COMMON MALLOW (*Malva sylvestris*),
ORDER *MALVACEÆ*.

1. Calyx and epicalyx 2. Fruit 3. Pistils, stamens and ovary

PLANT-LIFE

BY CHARLES A. HALL, F.R.M.S.

WITH 74 FULL-PAGE ILLUSTRATIONS
24 BEING FROM PHOTOGRAPHS
BY THE AUTHOR AND 50 IN COLOUR
FROM DRAWINGS BY C. F. NEWALL

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PREFACE

The author has endeavoured in this volume to present his readers with a clear account of plant life in its whole gamut, from the simplest microscopic forms to the most specialized flowering plants. It is hoped that the result of his efforts may be of some value to the amateur botanist and the lover of nature. It may also happen that this book will prove to be a useful, easy introduction to the study of more technical works.

Technical terms, which are the intellectual currency of the botanist, and imply in a single word or phrase what would be explained only in long sentences, have not been entirely avoided. Indeed, the author has been compelled to use a considerable number, but an effort has been made to lead up to their use in easy sequence, and to explain as tersely and clearly as possible what they mean. The glossarial index will assist the reader in discovering where the meanings of terms are explained.

The early chapters deal with the so-called cryptogamic plants, and the author trusts that what he has set down anent them may lead the amateur botanist, who has hitherto given attention solely to flowering

species, to take them into consideration, and make a study which cannot fail to add to his pleasure in the field. Besides, if one is to catch the real spirit of botany, and in any way grasp the principles of plant-life, these humbler plants must be taken into account. It is within their ranks that we get to the foundation of things, and they display phenomena that throw considerable light on the beginnings and earliest developments of plants.

According to a Hindoo proverb, "The carpenter is forgotten when the house is built." The author is not unmindful of the painstaking labours of a host of observers who have contributed to the fabric of modern botany. He has entered into a heritage of knowledge upon which he has freely drawn in confirming and supplementing his own observations. If he makes no pointed acknowledgments, it is because the workers to whom he is indebted are too numerous, not that he is ungrateful.

The coloured plates are from drawings by Mr. C. F. Newall; they are distinguished for a degree of accuracy made certain by the fact that Mr. Newall is a botanist as well as an artist. The black-and-white plates are from the author's own photographs.

CHARLES A. HALL.

MEIKLERIGGS,
PAISLEY,
1915.

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LIST OF FULL-PAGE PLATES IN COLOUR AND BLACK AND WHITE

PHOTOGRAPHIC PLATES ARE MARKED WITH AN ASTERISK.

There are in addition Eighty Figures in the Text.

PLANT-LIFE

CHAPTER I

INTRODUCTORY—ASEXUAL PLANTS

IN the beginning—PROTOPLASM. This wonderful substance, which Huxley has aptly called "the physical basis of life," received its name at the hand of Mohl of Tübingen in 1846. The term is derived from two Greek words—*prōtos,* first; *plasma,* form. Protoplasm is a slimy, gelatinous substance, of uncertain chemical constitution, fundamental to the existence of both plants and animals. It is known to contain carbon, nitrogen, oxygen, hydrogen, and some sulphates and phosphates of magnesium, potassium, and calcium; but no chemist has combined these constituents in such a way as to form living protoplasm. Besides the chemical components, the chemist has to reckon with the great factor Life—and Life is distinctly elusive. We have to bear in mind that the chemist in analyzing protoplasm must necessarily kill it in the process; he analyzes a corpse, from which the chief glory, Life, has been dismissed. Even supposing that the constituents of dead protoplasm may be combined in the laboratory in such a way that living protoplasm results, are we to conclude that Life has been created, that it would be a laboratory product ? Such a conclusion is by no means inevitable,

for may not the chemist have merely provided a combination of dead substances into which Life can enter, and through which it may manifest itself? Again, if it be claimed that the living product is due to chemical affinity, we naturally ask what this affinity is, and might reasonably conclude that it is an activity of Life itself. Perhaps it would be wiser to declare: In the beginning—Life; that Life is infinite, uncreate, without beginning, without end; that in Life nebulæ, suns, planets, plants, animals, and men "live, move, and have their being"; that this same Life, into whose Holiest Place we may not enter, is at the back of all physical energy and chemical affinity; that it manifests its activity not only within the limits of what we call living matter, but also in the combinations of the elements, the motions of the heavenly bodies, and all the phenomena of the inorganic world. One does not venture to dogmatize upon these profound problems, but one likes to think that it is not dead force, but living activity, that is engaged in forming the tangible from the intangible, in framing solid solar systems from meteoric particles or gaseous nebulæ. Chemical affinity, one might aver, never produced Life, but, on the reverse, one might say that chemical affinity is a phenomenon of Life. In the strict sense in which the biologist regards Life, he declares that protoplasm is its physical basis; but one is not always disposed to accept biological limitations, nor to confine the notion of Life to plants and animals alone. The imperialist claims to think imperially, but the philosopher aims to think universally, and so the latter chafes at the notion of a particular substance being the sole basis of Life. Thinking universally, he asks, May not matter in its

entirety be the physical basis of Life? Let this question be granted, it would then appear that the wonderful protoplasm, in its first appearing on this earth of ours so many æons ago, was a newly-formed organic life-form, a mode of the Life which hitherto, for excellent reasons, had been able to manifest itself only in activities associated entirely with the inorganic realm.

One thing is certain, there was a time in the history of the earth when no plant or animal could exist, when protoplasm, which is fundamental to their existence, had not appeared. And a time arrived when, as one might say, at the psychological moment, lo! protoplasm came into being. Certain conditions were assuredly necessary for its momentous appearance. The earth's crust would have to be sufficiently cool to allow of the condensation of water vapour into water, for water must have been the first abode of protoplasm and the first plants and animals. The chemical constituents necessary to the formation of the living substance must have been in solution in the water, and temperature and other factors, which, perhaps, elude the most scientific imagination, must have established a holy alliance in order that a stupendous and startling incarnation and virgin birth might result. And they are wise men, indeed, whose minds hark back with seemly reverence to the most momentous event in the physical history of the world—the advent of protoplasm.

Professor Schäfer, in his much discussed Presidential Address to the British Association for the Advancement of Science, assembled at Dundee in 1912, asked whether we are justified in assuming that only at a remote period in the history of the world, and as it were by a fortuitous

concomitation of substance and circumstance, living matter, presumably protoplasm, became evolved. He suggested that ancient conditions for the appearing of protoplasm were no more favourable than those which are at present in existence, and he was not sure but that its evolution might not still be taking place. These suggestions seem reasonable, and are the articulate expression of a feeling which must exist with many who are exercised about the origins of things. What has happened may surely happen again when the conditions are favourable. It seems more reasonable to think that protoplasm is still being evolved rather than that all that which now is has been derived from a modicum which evolved æons ago.

Our speculations are attractive, but we must come down to facts. The fundamental fact in plant and animal life is protoplasm, and a further fact is that it has been differentiated, from a period most remote, into plant and animal forms. Into the mysterious forces which led to such differentiation we shall not venture to inquire; we shall simply take facts as we find them. And one outstanding fact in relation to the simplest life-forms is the difficulty of deciding which is plant and which is animal. The old idea that plants are stationary and animals move does not hold good as a means of distinguishing between the two great kingdoms of nature; for there are undoubted plants which swim actively, and the living protoplasts in a tree as stationary as an oak certainly move within the narrow confines of their cell walls. Moreover, there are animals which are sedentary—for example, the sponges, which

take up a fixed position from which they do not move. The nature of the problem before us will, however, be better appreciated if we make a study of some of the lower organisms.

In Fig. 1 we have a drawing which represents that remarkable organism known as *Amœba proteus* as seen under a fairly high power of the microscope. Specimens may be found on the surface of mud on the bottom of fresh-water ponds or pools. To the naked eye they are mere specks, for they are seldom more than $\frac{1}{90}$ inch in diameter. We place a drop of water containing one or more of these specks on a glass slip, and, having covered the drop with a thin cover-glass, proceed to microscopic examination. At first we experience some difficulty in locating our interesting subject, because, owing to the disturbance of the even tenor of its way, it is quiescent and hardly distinguishable among the fine particles of débris scattered in the thin film of water. In a short time, however, we shall observe signs of movement, and be able to note several interesting details. *Amœba* is a speck of protoplasm of no definite form, yet capable of assuming many forms, in which respect it is thoroughly protean and altogether worthy of its specific name. Under a magnification of, say, 250 diameters, the main

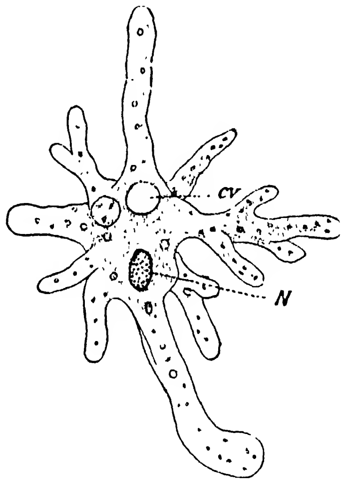


FIG. 1.—AMŒBA PROTEUS.
c.v., Contractile vacuole; *n*, nucleus.

substance of this organism—that is, the endoplasm—is seen to be granulated with tiny particles of solid matter, while the ectoplasm, the outer surface or rind, is devoid of granules, and evidently firmer and less fluid than the granular endoplasm; yet it is highly elastic, as the movements of the organism show. And concerning these movements. They consist mainly in the formation of pseudopodia, or false feet. Portions of the body-substance are extended to form lobes or processes, as shown in the figure. These are the pseudopodia, the extension of which enables the *Amœba* to slowly change its position. It is calculated it can thus creep a distance of $\frac{1}{25}$ inch in about an hour. Another movement, within the body, is the repeated formation and disappearance of a clear globule known as the "contractile vacuole." This curious movement is due to the gradual accumulation at a particular point in the body of a drop of water which, having attained its maximum, is speedily discharged. We may assume that the function of the contractile vacuole is excretory. A third movement is that involved in feeding. The *Amœba* comes across some delectable morsel of organic food, such as a diatom, and proceeds to make a meal of it. Pseudopodia are extemporized as a means of grasping the food; in due course they reach round it, retract, and the food particle is now enclosed in a food vacuole in the substance of the organism. There, in that species of stomach made-to-order, the food is acted upon by a digestive ferment and so dispatched.

A point of exceptional interest in the constitution of the *Amœba* is the nucleus. This is a little round body in the endoplasm, of a somewhat mottled appearance.

It is not easily made out under ordinary conditions, but if the organism be killed and stained with iodine, the nucleus is stained a deeper brown than the rest of the protoplasm, and thus becomes easily apparent. Now we must consider the nucleus with some degree of reverential awe, for it is the vital centre, that structure through which Life itself regulates the existence and activities of a cell; it is the very heart of an organism, and even more. When an *Amœba* reaches its maximum growth it divides into two, a process of reproduction known as "fission." But in this division the nucleus is always first divided; indeed, it regulates the division. If an *Amœba* be cut in two, and a part of the nucleus be included in each half, then each half will develop into a perfect individual; but if, in making the cut, the nucleus is not divided, then the part containing it will become a perfect individual, but the other part, although it may live for a few days, and even send out pseudopodia, cannot creep, nor can it digest food, although it may enclose it.

What, then, are our conclusions in regard to *Amœba?* In the first place it is a cell, or protoplast, without a firm cell-wall. It can extemporize feet, and so move; it can capture food and digest it in an extemporized stomach; it can reproduce its kind by the simple method of fission; it is a speck of nucleated, living protoplasm displaying animal characteristics; it feeds upon organic food, such as microscopic plants; it cannot live in the absence of such food; it is an animal, like all other animals, utterly dependent, so far as food is concerned, upon other organisms, for it cannot live on inorganic substances. Before animals, no matter how small or

lowly, could exist, it was essential that other organisms capable of feeding and thriving upon inorganic substances should make their existence practicable. Such organisms, as the sequel will show, are plants.

So we have no difficulty in deciding to which category *Amœba* belongs; it is certainly an animal. But we can come to no easy or certain conclusion with regard to those curious organisms commonly known as "Slime-Fungi," and technically designated MYXOMYCETES (Gr. *myxa*, mucus; *mykēs*, a fungus), or Mycetozoa (Gr. *mykēs*, and *zōon*, an animal). Over 400 species of Myxomycetes have been described; they occur on rotting leaves, wood, tan, etc., in damp situations; but although they are common, they do not seem to be known by persons other than naturalists. Yet they are of profound interest, for in no other organisms have we the opportunity of studying protoplasm without the limitations of cell-walls in such great mass. One species, *Fuligo varians*, or "Flowers of Tan," is frequently seen in summer on damp tan-bark; it is of creamy consistence, bright yellow in colour, and often extends to a breadth of about a foot. Thus seen, *Fuligo* is in its vegetative state, occurring as a mass of naked protoplasm; later, it passes into the reproductive stage. The life-history of a Myxomycete is very simple: the mass of naked protoplasm, called a "plasmodium" (*plasm*, a mould, or matrix), creeps slowly on the surface, say, of decaying wood, feeding and growing the while. In due course the organism ceases to feed, and a startling change takes place, for the plasmodium is converted either into a single fruit (sporangium) or a number of sporangia, in which a mass of

dustlike spores are formed. These spores are ultimately liberated, and, being very light, are distributed by even the slightest currents of air; reaching a suitable substratum, they germinate into active swarm-spores, which either swim in water, with the assistance of lash-like processes, called "flagella," or creep over damp surfaces of dead leaves, etc. These swarm-spores feed, grow, and repeatedly divide; finally, they coalesce, to form a plasmodium. Thus, the life-cycle is from plas-

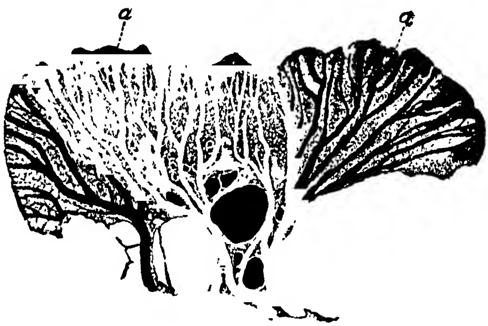


FIG. 2.—BADHAMIA UTRICULARIS, PLASMODIUM, DRAWN FROM A STAINED SPECIMEN PREPARED BY MR. A. LISTER.

a, *a*, Advancing margin. × about 5.

modia to spore-production. The spores develop into swarm-spores, and the latter settle down into plasmodia.

In Fig. 2 we have a drawing of a small plasmodium of the Myxomycete, *Badhamia utricularis*, which is often found on decaying wood, and even on the rotten timbers of old garden-seats. It should be sought in damp weather. It occurs in deep-yellow, slimy, flat, irregularly formed masses, feeding on species of fungi growing on the rotten wood. As the drawing indicates, thick veins of protoplasm traverse the mass, forming a species of network within which the living substance is in very

active movement. Microscopic examination reveals the fact that the plasmodium, as in all Myxomycetes, contains a great number of nuclei (p. 6), which are shown in Fig. 3. These nuclei increase by fission, and regulate the growth of the plasmodium. No part of the mass is in the slightest degree cellular. If we will, we may see the organism feed. We place a portion of the fungus which the Myxomycete relishes in front of the creeping margin of the plasmodium, which soon flows over the food, engulfs it, and digests it in food vacuoles, after the manner of an Amœba; indigestible portions—the "bones," as it were—are disgorged. The active plasmodium creeps in the direction of moisture, and avoids strong light; but when it is ready for spore-formation, it creeps away from a damp substratum to the driest location it can find, and also courts strong light. In a period of drought, the plasmodium, probably for self-preservation, may cease its activity, divide into a number of parts, each part containing a number of nuclei, and forming a cell-wall of hardened protoplasm. This process is called "encystment," each cell being a cyst, and the mass of cells is named a "sclerotium"

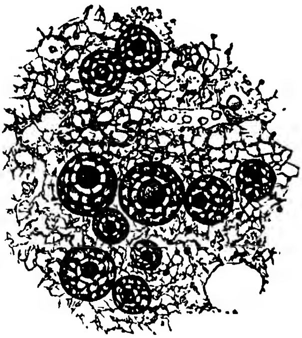


FIG. 3.—BADHAMIA UTRICULARIS; PORTION OF PLASMODIUM, × 1200, SHOWING SPHERICAL NUCLEI.

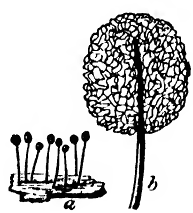


FIG. 4.—(OBTUSATA.
a, Group of sporangia, natural size; b, empty sporangium. × 16.

(Gr. *sklēros*, hard). In this form a Myxomycete may live for some years. When a sclerotium is damped, the walls of the cysts are softened, and the organism resumes its plasmodial form and activities. Fig. 4 shows a group of the fruits, or sporangia, of the species *Comatricha obtusata*, as well as an empty sporangium. The spores which are formed in these vessels are quite dry when they are exposed for distribution, and in a dry

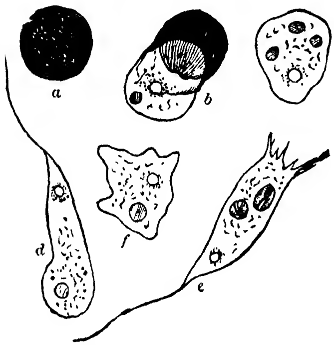


FIG. 5.—SLIME-FUNGUS DIDYMIUM DIFFORME.

a, Spore; *b*, swarm-cell emerging from envelope; *c*, swarm-cell newly hatched; *d*, swarm-cell with flagellum; *e*, swarm-cell with bacteria in food vacuoles; *f*, swarm-cell in amœboid form. × 720.

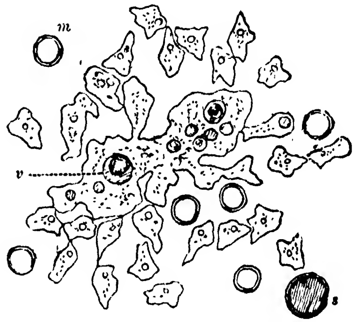


FIG. 6. — DIDYMIUM DIFFORME; SWARM-CELLS ASSEMBLING AND COALESCING TO FORM A PLASMODIUM.

m, An encysted swarm-cell; *v*., encysted swarm-cell being digested in a vacuole; *s*, empty spare envelope.

condition they retain their vitality for an indefinite time. They can germinate only in moisture. The formation and appearance of the swarm-spores is shown in Fig. 5. The swarm-spores swim with what is described as a "dancing movement"; they can digest solid food; they increase by fission, and in a time of drought may become encysted. As already stated, the swarm-

spores ultimately coalesce, to form a plasmodium; but before this occurs, they lose their flagella, ceasing to swim, and contenting themselves with creeping movements of an amœboid type. The assembling and coalescence into a plasmodium is illustrated in Fig. 6.

From this brief sketch of the life of the Myxomycetes we see that in their plasmodial forms, and as regards their swarm-spores, they can digest solid food after the fashion of *Amœbæ*, and in this and other respects display distinct animal characteristics. Moreover, they are dependent upon organic material for nutrition, as is the case with all animals. At the same time we know that there are undoubted plants, such as the fungi and bacteria, which, unlike green plants, do not build up inorganic material into organic form, but depend upon organic material in nutrition. But these plants absorb food in solution through their cell-walls, and do not eat solid material. But in the matter of spore-formation and reproduction, the so-called " Slime Fungi " display some likeness to fungi and therefore we need not wonder that in the past they have been claimed as animals by zoologists, and as plants by botanists. The modern attitude towards them is that of discreet agnosticism, and there is a distinct inclination to relegate them to a position in the genealogical tree of Nature peculiarly their own.

The Bacteria, which we propose to consider briefly, are classed as plants. Popularly known as " microbes," they are regarded with horror by a public which associates them entirely with disease. True it is that bacterial organisms have an intimate connection with such

diseases as anthrax, cholera, diphtheria, leprosy, tuberculosis, and others; but we ought not to hastily condemn all Bacteria as workers of evil because some of them are associated with disease. As a matter of fact, we should be in a very bad case indeed were it not for the beneficent activities of hosts of these exceedingly minute plants, and it is reassuring to know that some forms which are parasitic in the human body are practically harmless. This is the case with a number of forms which live on the mucous membrane of the mouth, and a particular species, *Sarcina ventriculi*, found in groups, or packets, in the alimentary canal. Bacteria, in general, are either parasites, in which case they live at the expense of living plants or animals, or saprophytes (Gr. *sapros*, rotten; *phyton*, a plant) feeding upon dead and decaying organic matter; and the saprophytic forms have an exceedingly important place in the economy of Nature, for they are the chief agents in breaking up dead plant and animal bodies, and rendering their substances fit for absorption by higher plants. Without the good offices of Bacteria, the higher plants would certainly suffer, and we know that animals and men could not exist without the ministrations of the plants. Then there are Bacteria which are actually able to fix free nitrogen from the atmosphere and make it available for the food of plants with which the organisms are associated. Such Bacteria occur in tubercles on the roots of plants of the Pea order; they seem to provide the host-plants with nitrogen, which is essential to the existence of protoplasm, in exchange for bed and board. Thus, it happens that many plants of the Pea order (leguminous plants), being infected with

nitrogen-fixing Bacteria, enrich the soil in which they grow, and it is not uncommon for agriculturists to plough in crops of leguminous plants in order to increase the fertility of the soil. The fact that Bacteria are agents in the purification of sewage should also be placed to their credit.

Bacteria are practically ubiquitous. If we ascend the hills, they are there, for they have certainly been recorded at an altitude of 10,000 feet. They abound in soil and water, even in the water we drink, which, by the way, would be decidedly "wersh" without their presence. They also float about in the air, and are distributed amongst the dust which we raise with our feet as we walk. When we inhale the fragrance of flowers, we may draw Bacteria from the petals into our nostrils. When we kiss, we may "exchange microbes." When we stroke a dog, we may scatter a host of these organisms. It has been calculated that no less than 50,000,000 of Bacteria may be contained in so little as an ounce of roadside dust. Their size is so exceedingly small that in the case of such a germ as that of the Bubonic Plague 250,000,000 would cover about a square inch of soil, and be able to thrive on it. The average short diameter of the Bacteria is said to be about $\frac{1}{25000}$ inch. These organisms are not easily killed; they can survive great extremes of temperature. In an experiment a number (forty-four) were exposed to the intensely cold temperature of $-210°$ C., yet were able to survive. Dry spores resist high temperatures; they have survived a ten minutes' exposure to 150° C. Nor need we think that mere boiling will kill certain spores, for some are known to be able to survive even after being boiled at a temperature of 100° C. for several hours.

The Bacteria are the smallest known plants, and when we consider the infinitesimal result of the activity of a single individual, and yet grasp the enormous effects of the activity of Bacteria in the aggregate, the pessimists among us, given to minimizing the importance of the human unit, may well take heart of grace. But while these organisms teach us the value of the unit, we shall have no desire to emulate them in the matter of multiplication. It is calculated that a single microbe, under very favourable conditions, may have millions of descendants in a few hours! The bacterial population of ½ cubic inch of cream standing about forty hours may reach to 500,000,000! Most Bacteria love darkness rather than light, and are killed by direct sunlight in a few hours; they can stand diffused light much longer. But some species of the Purple Bacteria—able to feed on sulphide of hydrogen—thrive well in light, and are attracted by it.

Some authors consider Bacteria to form a distinct group of Fungi; they certainly display fungal characters; but perhaps it is premature to declare definitely that they are Fungi, for we have yet much to learn about them. They may be described as very minute one-cell plants of the simplest structure, of a parasitic or saprophytic nature, some of them capable of active movements, and all, without exception, multiplying by transverse division or fission; they may also produce resting-spores or -cells. They vary in form, and for convenience in description are commonly classed as:—

1. Spherical = *Cocci* (singular, *coccus*).
2. Rod-like = *Bacilli* (singular, *bacillus*).
3. Bent or Spiral Rods = *Spirilla* (singular, *spirillum*).
4. Higher or Filamentous Bacteria = *Trichobacteria*.

The existence of a nucleus in the bacterial cell has not yet been satisfactorily demonstrated. The cell is enclosed in a cell-wall, which is generally protein in character, and is thus very similar to the animal cell-wall. Cellulose, as the usual substance of vegetable cell-walls is named, occurs in some Bacteria. The cell-wall is permeable by water, and it is always through the wall that the organism absorbs its nourishment in solution. Bacteria cannot engulf and digest solid particles of food after the manner of animals. There are a few Bacteria which are neither parasites nor saprophytes, as, like the Purple Bacteria already referred to (p. 15), they derive their food from inorganic sources. In this respect they resemble the green plants. With a few exceptions the organisms are colourless: the Sulphur Bacteria possess a purple pigment, and there is green colouring-matter, regarded by some investigators as chlorophyll, the colouring-matter of ordinary green plants, in *Bacterium viride* and *B. chlorinum.* Possibly the green species ought to be classed among the Blue-Green Algæ, to which reference will shortly be made. Most Bacteria are not motile, yet many forms have power of locomotion, due to the possession of protoplasmic lashes (cilia, or flagella), with which they lash the fluid medium in which they exist, and so secure movement. These lashes are so extremely fine that they do not appear in microscopic examination unless stained.

In order to form a definite conception of the life-cycle of a Bacterium, we will consider one of the rod-like forms possessing flagella—*Bacillus subtilis* (Fig. 7). A plentiful supply can be readily obtained by boiling a

small quantity of hay in water for somewhat less than a hour. After boiling, the liquid is left to stand for a time, and it is not long before *B. subtilis*, the Hay Bacillus, makes its appearance in great numbers. Needless to say, we cannot study the organism without a high-power microscope, for a single isolated cell is but $\frac{1}{25000}$ inch in diameter, and from five to eight times that extent in length. A satisfactory examination can be made with a combination of lenses yielding magnification of 1,000 diameters. Each cell is seen to have a distinct cell-wall. The cell-contents completely fill their investment, and for a time the cell is in active movement, the movement being due to the lashing of flagella (see Fig. 7, *a*), which are not apparent unless the organism is stained by a process familiar to microscopists. The Bacillus is observed to multiply rapidly by repeated fission. But in a few days the cells seem to get tired of their hitherto ceaseless activity; they rise to the surface of the water, and rest there in long threads, the cells being connected end-to-end. At the same time the cell-walls become gelatinous, and the organisms form a gelatinous mass, known as the *zooglœa* stage, on the surface of the liquid (Fig. 7, *e*). As long as the conditions are favourable for growth, the cells continue to multiply by division, but when the food-supply in

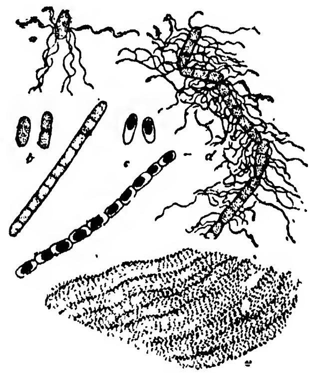


FIG. 7.—BACILLUS SUBTILIS. *a, d*, Ciliated motile cell and filament; *b*, non-motile cells and filament; *e*, zooglœa, × 175; *c*, cells and endospores from the zooglœa; *a-d*, × 1050.

the water is exhausted, the cells constituting the threads form spores, which, in the case of *B. subtilis*, are endospores, being formed inside the cells. Only one spore is formed per cell (Fig. 7, *c*), so spore-formation is not for multiplication, but for a resting condition, in which the organism can tide over unfavourable circumstances. The spores possess astounding vitality; they are not injured by being dried, and can endure adverse conditions very long periods—until, indeed, they find a suitable substratum in which they can germinate. Having found a proper food solution, the spore-membrane bursts, setting free the cell-contents, which speedily resume the normal activities of a bacterium. Such is the career of the Hay Bacillus, which may be regarded as typical of its class. It will be remarked that there is not the slightest trace of sex in these organisms.

But where are we to place the Bacteria in the genealogical tree of plant-life? Their minuteness and simplicity might lead a superficial observer to place them among the first plants, to say that in them we surely have the very beginnings of plant-life; but such an observer would overlook weighty facts. In the first place, the great majority of the Bacteria are parasites or saprophytes, utterly dependent upon existing organic matter for food; therefore they must benefit by the activity of plants which can build up organic bodies from inorganic materials. Again, their general antipathy to light, and parasitism, indicate degradation rather than the upward trend. We may surmise that the Bacteria have descended from minute motile plant forms, which in one direction have given rise to the green plants

seeking the light, and in another direction have developed the bacterial habit, which, as we have seen, plays an important part in the economy of Nature. But the fact that there are some Bacteria which are independent of organic food, and derive all their food-supplies from mineral sources, makes one think furiously: these forms possess no chlorophyll, which has always been regarded as essential in the transmutation of the inorganic into the organic. Perhaps the purple pigments peculiar to these exceptional Bacteria takes the place of chlorophyll, but the existence of such forms seems to point to the possibility of the existence of early life-forms, which could build up organic compounds without the assistance of chlorophyll. As Dr. Douglas H. Campbell says in his *Evolution of Plants*: "The restriction of this power to green cells is possibly a secondary condition."

We have several times alluded to the pigment chlorophyll, or leaf-green, and, as we are approaching the study of green plants, it is essential that we should understand the use and significance of this substance. It is well known that a potato contains much starch; this constitutes a reserve store intended for the nourishment of young potato-plants. A potato will "sprout" without being placed in the soil, and the sprouts will grow for a time; growth, indeed, continues until the reserve material in the tuber is exhausted. If the sprouting takes place in the dark, the sprouts will not be green, but they develop a green colour in sunlight. Even a potato tuber lying on the soil will become green on the surface exposed to the light, but the surface resting on the soil develops no green pigment. In this and a

score of other ways we may learn the truth that amounts to a botanical axiom—no sunlight, no chlorophyll. Moreover, it is demonstrable that this pigment occurs only in parts of plants to which sunlight penetrates; in the cells of the interiors of plants, which sunlight cannot reach, there is no chlorophyll, as we can easily realize when we cut a twig of a tree transversely, and notice that the major portion of the section is not green, and that the green of the twig is confined to its circumference. Garden celery is bleached by being "earthed-up." In order that chlorophyll may be formed in the cells of a plant, it is essential that they should contain a small modicum of some salt of iron in solution. Plants grown in solutions from which iron has been purposely omitted are affected with chlorosis; they are sickly and pallid. A very minute quantity of an iron salt added to the water will quickly remedy the trouble, for then chlorophyll is rapidly formed, in the presence of light, and performs its important function in plant-economy.

But why does the potato-shoot produced in the dark die when it has exhausted the reserves of food in the tuber? Or, to put the obverse question, why does the shoot growing in sunlight continue to grow after all reserves in the tuber have been used up? In the former instance no chlorophyll is developed, while in the latter it develops in abundance. The conclusion is that chlorophyll is most intimately associated with plant nutrition; that in its absence plants cannot assimilate essential food elements. Now, it happens that about half the solid substance of plants consists of one element, carbon; this is a *sine qua non* of plant existence, and, without the slightest doubt, the carbon required by

green plants is derived entirely from the atmosphere, in which it is found in the form of what is popularly called "carbonic acid gas," but which is more correctly named "carbon dioxide" (CO_2). In most green plants there are tiny pores or mouths, called "stomata" (Gr. *stoma*, a mouth), which occur in great numbers in the epidermis of the leaves and green stems, and it is by means of these openings that carbon dioxide is admitted. In completely aquatic plants there are no stomata, but in their case the carbon dioxide in solution in the water is absorbed through the cell-walls. When we examine the cells of the green part of a plant under the microscope, we see that the colouring matter, chlorophyll, is not uniformly diffused through the cells, but is confined to little bodies of protoplasm which are denser than the colourless protoplasm of the cells. These tiny bodies are saturated with chlorophyll; they are variously named "chlorophyll-corpuscles," "-granules," "chloroplastids," or "chloroplasts." We shall know them by the last-mentioned term. In Fig. 8 we have a diagram of cells containing chloroplasts, some of which are dividing, for they multiply by fission. The little bodies inside the chloroplasts are starch, and the chloroplasts are shown to be tiny chemists engaged in the manufacture of starch. Now, starch is a carbon compound; it is composed of carbon, hydrogen, and oxygen, its chemical formula being $C_6H_{10}O_5$. By what manner of alchemy do the chloroplastic chemists produce this compound? Be it noted, the process involves the conversion of the inorganic into the organic, which is a remarkable feat. Remembering the constitution of starch, we can see that two out of the three elements required for its formation

are contained in carbon dioxide, which reaches the chloroplasts from the atmosphere. But whence the hydrogen? This is undoubtedly derived from water in the cell, for water is composed of hydrogen and oxygen (H_2O). So in water and carbon dioxide, the chloroplasts have the elements they require for starch manu-

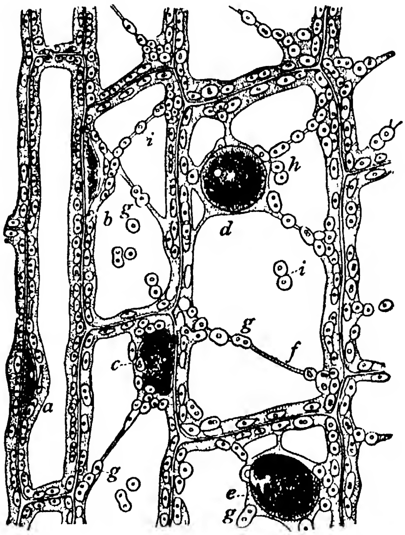


FIG. 8.—CELLS FROM LEAF OF AMERICAN WATER-WEED (ELODEA). HIGHLY MAGNIFIED.

a, b, c, d, e, Nuclei of cells; *f*, strand of protoplasm which crosses cell-cavity; *g, h, i,* chloroplasts, some of which are dividing.

facture. But they need something in addition to the elements before they can achieve their alchemy, and that something is energy: how do they get it? Well, we know that carbon assimilation and starch formation are dependent upon sunlight, and are sure that the chloroplasts get their energy from the sunlight. The fact is, these tiny protoplasmic bodies somehow use the pig-

ment chlorophyll in transforming the radiant energy of light into chemical energy, and this energy enables them to form organic compounds from mineral matter. What has been said about starch formation is not to be regarded as a statement of all that is involved in the business; it is a rough outline of a complicated piece of chemistry. The chlorophyll may be extracted from a leaf by soaking it in alcohol. The alcoholic solution appears bright green when we look through it, but it is fluorescent, and when we see it in reflected light, it appears blood-red. After we have extracted the chlorophyll, we can demonstrate the presence of starch in the chloroplasts by treatment with tincture of iodine; this reagent turns the starch blue. We see, then, that sunlight is necessary for the formation of chlorophyll, and also in carbon assimilation, and, moreover, that the pigment formed in sunlight is used by the chloroplasts in transforming radiant energy into chemical energy. The appearing of protoplasm was epochal in the history of the world, and, we may safely aver, the development of chlorophyll was an advance fraught with almost as mighty issues. Green plants are of the utmost importance as carbon assimilators and manufacturers of organic compounds; they constitute the fundamental food-supply: we could not exist without them, and they could not do their beneficent work in the absence of leaf-green. We take off our hats to chlorophyll!

The reader will have already gathered from what has been written that there are plants which do not possess chlorophyll, and it will be obvious that they must secure carbon compounds differently from green plants. Among such plants are the Fungi, which, either as

saprophytes or parasites, obtain their food-supply from organic matter made possible by green plants; and also parasitic flowering plants such as the Broomrape and Toothwort, which absorb their nutriment from the tissues of their living hosts.

Furnished with some knowledge respecting the use of chlorophyll, we are prepared to advance another step in our study of the humbler forms of plant-life. The Bacteria, to which we have devoted some attention, are often classed as SCHIZOPHYTA (Gr. *schizein*, to cleave; *phyton*, plant), or Fission-Plants, from their manner of multiplication, and the Blue-Green Algæ (Cyanophyceæ) come under the same category. These minute blue-green plants, of which about 800 species have been distinguished, are all too small for naked-eye observation. They contain chlorophyll and an additional blue pigment, phycocyanin, which, unlike chlorophyll, is soluble in water; this pigment gives the cells a bluish, reddish, or violet cast. They occur in stagnant water, on damp earth, in the sea, embedded in the tissues of other plants, and some of them are associated with certain Fungus plants which form Lichens. The structure of the cell is simple. In its centre is a colourless body which is thought by some to be a nucleus, but it is questionable if a duly constituted nucleus exists. The cell-wall is gelatinous, and it is owing to the swelling of this gelatinous membrane and its adhesive nature that the cells, or filaments of cells, cling together and form colonies. Chitin may also occur in the cell-wall. The Blue-Green Algæ thrive in great extremes of temperature: they are found thriving in thermal springs at a temperature up to 85° C., and can exist in glacier streams. After

the famous eruption of Krakatoa, whose streaming lavas destroyed all vestiges of life in the area over which they poured, the first plants to colonize the lifeless lava-waste were Blue-Green Algæ. They have been recognized as the first plant colonists of fresh lavas in other places. In 1874 a species (*Dermoglœa Limi*) appeared in the sea off the Adriatic coasts, and multiplied so extensively that the fishing industry was seriously hampered, but after six weeks the nuisance suddenly disappeared.

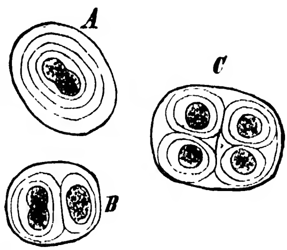


FIG. 9.—GLŒOCAPSA POLYDERMATICA (*STRASSBURGER*). HIGHLY MAGNIFIED.

A, Beginning to divide; *B*, shortly after division; *C*, a later stage.

The simplest Blue-Green Algæ are included in the family Chroococceæ; they are all one-cell forms which have the habit of cohering in colonies. One genus, *Glœocapsa* (Fig. 9), establishes itself in small gelatinous colonies on damp walls and rocks, and not infrequently on hot-house window-panes. Stagnant water is frequently covered with films of *Merismopedia*. The method of multiplication is that of simple fission.

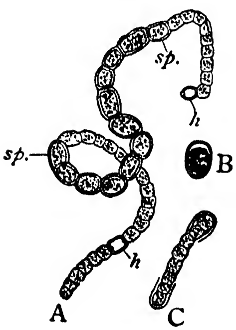


FIG. 10. — NOSTOC LINCKII. × 470.

A, Portion of a filament; *h*, *h*, hetero-cysts; *sp.*, *sp.*, spores; *B*, germinating spore; *C*, young filament from spore;

filamentous form. It occurs commonly in round, bluish-green, jelly-like masses on damp soil, in farmyards, on walls and garden walks.

The genus embraces a number of species, some of which are found in water. The masses are quite evident to the unaided eye. On examining them microscopically we see that the transparent jelly protects a colony of filaments which wind about in all directions, each filament being composed of tiny round cells arranged like beads on a necklace. The jelly in which the filaments occur is, of course, secreted by the cells. The cells are filled with protoplasm, and no defined chloroplasts exist; the pigment is diffused throughout the protoplasm. As the diagram shows, somewhat larger cells appear at intervals in the strings of cells; these are called "heterocysts." They are emptied during the growth of the filaments, and it would seem that they act as food stores, which are drawn upon when required. *Nostoc* is propagated either by the breaking of the filaments into sections, each section worming its way out of the mass—a movement which has not been explained—and giving rise to a new colony, or by the formation of spores. These spores are developed from ordinary cells which grow larger than their fellows and secrete a stout cell-wall. They break away from the filaments in which they grow, and, under suitable conditions of moisture, germinate and give rise to new filaments. The spores are not killed by drought; they are evidently a provision for tiding over adverse conditions.

It is questionable whether the Cyanophyceæ should be classed with the Algæ, and it is only from "use-and-want" that we have referred to them under that name. As already indicated, they are true Schizophytes, or Fission-Plants. Like the Bacteria, they multiply by fission and show no trace of sex, but they are dissimilar

from the Bacteria in that no forms bear flagella. Perhaps we had better regard them as a side-line in the evolution of plant forms. Their possession of chlorophyll indicates ability to manufacture carbon compounds, but it is doubtful whether they are completely independent of provided organic food. The mode of occurrence of some of them, at any rate, points to the possibility of a partially parasitic or saprophytic habit. One thing is certain, they are an extremely simple and primitive type of plants.

One might say that this chapter is arrayed in motley, for we have assembled for description some heterogeneous types of life-forms. From an undoubted animal form we progressed to the Myxomycetes, which may be animal or plant, or both; then we proceeded to deal with undoubted plants, the Bacteria and Blue-Green Algæ, whose origin and relations are extremely doubtful. The forms dealt with are of great simplicity, and one feature in regard to them all is the absence of sex. The probability is that the earliest forms of life, both plant and animal, reproduced asexually, and that sex was a later development—one fraught with the utmost importance.

CHAPTER II

THE DEVELOPMENT OF SEX IN PLANTS AND A STUDY IN EVOLUTION

So far we have confined our attention to the study of life-forms which multiply asexually. It will be interesting, in the present chapter, to consider, at least in part, the beginnings of sex in plants, and to trace it from its simplest manifestation through some stages of its development.

We shall begin with those wonderful, microscopic, one-cell plants familiar to even the most amateur microscopist as DIATOMS (Gr. *dia*, through; *temnein*, to cut). They occur in vast numbers and extraordinary variety in both salt and fresh water, on damp soil, among moss, in the drifting plankton of lakes and seas, on the surface of the mud of ponds and pools, on wet stones and rocks, attached to aquatic plants and decaying vegetation. Many forms are solitary, others exist in colonies; some float freely, others attach themselves to an anchorage by means of gelatinous stalks. The cells in some instances form zigzag chains or bands. The form of the cells varies most remarkably; it may be rodlike, circular, oval, wedge-shaped, or curved. The protoplasmic cell contains a single central nucleus and colour-bearing bodies called "chromatophores," which may be few or many. These chromatophores are tinged

by a brown pigment, so that living Diatoms usually appear brown, but the pigment masks the green chlorophyll, which is occasionally seen in dead specimens. Oil globules also occur in the cells.

The cell-wall of a Diatom is of peculiar interest: it consists of two siliceous (flinty) valves, or frustules, which fit one over the other like the lid on a box. The manner in which they fit may be well illustrated by the two halves of those telescopic baskets used for carrying luggage. It is remarkable that a cell so minute should be able to elaborate so wonderful a structure for its protection. And no less remarkable than the existence of a cell-wall which is practically imperishable is the marvellous way in which the valves are marked with ribs, pits, dots, etc., constituting a natural artistry inimitable in its extreme fineness by any engraver or sculptor. In some species there are pores through which the cell forces a gelatinous secretion. These siliceous frustules are not destroyed even by intense heat, and the microscopist may clean them by boiling them in nitric acid without impairing their form or beauty. Some forms make valuable test objects for microscope lenses.

Now, how do Diatoms multiply? In the first place by longitudinal division. It will be obvious to the thoughtful reader that the cell is "cabined, cribb'd, confined" within its decidedly inelastic cell-wall, which will not expand with growth. When, therefore, the cell is up against the housing problem on account of its increased proportions, it must necessarily divide. What happens is this: The growing cell pushes its valves slightly apart, division is effected parallel with the

faces of the valves, and each half of the cell, now become an individual, retains one of the valves, and completes its integument by forming a new valve to fit inside that retained from the parent cell. Thus the two valves of a Diatom resulting from division are invariably of different ages, and we can see, moreover, that repeated division inevitably leads to diminution in size of the daughter-cells, and if the process were to go on indefinitely, it would be extremely unsatisfactory. The cells would get smaller and smaller, and ultimately so small that the plants would be threatened with extinction. But division and its consequent reduction in size proceed to a certain length, when the process is arrested. Growth and a return to normal proportions is provided for by the formation of auxospores (Gr. *auxē*, growth). The cell contents mass together, free themselves from their valves, grow considerably, and finally secrete new valves. These valves are thus of the same age as each other.

So far there has been no sign of sex, and, be it said, sex is not conspicuous among the Diatoms. Nevertheless, it does appear, for it sometimes happens that two cells conjugate, and unite to form a single auxospore; and over and beyond this evidence of sex, it may also happen that two cells may divide each into two daughter-cells, which conjugate in pairs, the result being the formation of two auxospores. Yet we note that, although sex appears among the Diatoms, there is no distinction of sex; we cannot say of two conjugating cells which is male or which is female.

Diatoms play an important part in the economy of the life of the sea, as they form a food-supply for hosts

of small animals and a few quite large ones. Their empty frustules, also, sink to the ocean floors, and form deposits of geological importance.

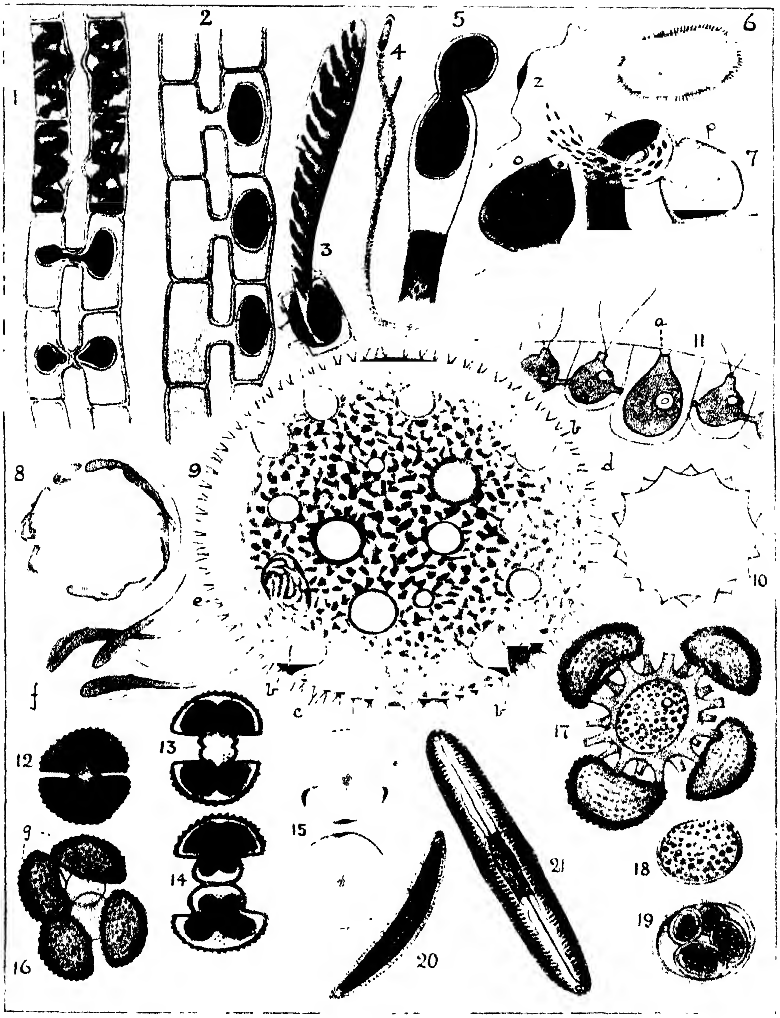
There are some Diatoms which move in a gliding or creeping manner. They must necessarily be of the unattached kind and of suitable shape. The *Naviculæ* (little boats) are among such forms familiar to the microscopist. They may be seen moving across the field of the microscope like tiny ships; they frequently halt in their onward progress, reverse engines, as it were, and move backward as easily as forward. They are also to be seen rotating on their axis. *Encyonema* occurs in colonies in a gelatinous filament, and each cell is able to move backward or forward within the limits of the filament. It is difficult to explain these spontaneous movements; they may be due to a sheath of protoplasm surrounding the valves or the extrusion of minute threads of the same substance through pores in the frustules. A free-moving form, *Pinnularia viridis*, is shown, as seen under a medium microscopic magnification, in Fig. 21, Plate II.

Exactly where Diatoms are to be placed in the gamut of plant-life is not decided. They are often included among the Algæ. They give little, if any, indication of their derivation, nor do they appear to be a step in any particular direction. We may regard them as one of Nature's side-issues ending in a cul-de-sac. That they are of economic importance as well as natural interest has been shown. They are of moment to our present study on account of their display of sex.

In furtherance of our argument, we turn from the brown Diatoms to the exquisitely green Desmids. These

minute plant forms are of singular beauty; they are classed with the Green Algæ (Chlorophyceæ). Over 1,000 species have been distinguished, all of which occur in fresh water. Some species are found in ponds, but as a rule these plants thrive best in open situations, so that Highland lochs and moorland and bog pools are the best hunting-places. Some are found free in the water, and can be secured with a fine net; others are attached to plants or the muddy bottom of the pool. Sunlight generally attracts them to the surface. When very numerous, they give a green tint to the water. There are many one-cell species, but multicellular forms occur in which the cells are attached in rows, and so form threads, or filaments. It should be noted, however, that the cells of the threadlike forms exhibit the habits of the one-cell forms, and it is questionable whether such forms should be regarded as multicellular plants: the thread might rather be looked upon as a series of one-cell plants, which are independent units in all points but that of their attachment in rows.

The Desmid cell, which exhibits great variety of form in different species, almost invariably displays two quite symmetrical halves, which are very frequently marked off from each other by a constriction forming a sort of neck, or waist, between them. The cell-wall, which is often sculptured, lobed, covered with protuberances, and furnished with pores, is in two halves or valves, the edges of which meet at the constriction, or median plane. The cell-nucleus occurs in the median plane, and a colour-bearing body (chromatophore), which may be radiate in form, or composed of several plates, occupies the greater part of each half of the cell. Pyrenoids,



FRESH-WATER ALGÆ.

1. *Spirogyra*, in conjugation
2. ,, Zygospores formed in one filament
3. ,, Germination of zygospore
4. *Vaucheria sessilis*, branched filament with root processes
5. ,, Asexual reproduction; zoospore escaping
6. ,, Zoospore free
7. *Vaucheria*, Sexual reproduction: x. Antheridium o. Oögonium z. Spermatozoids

8, 9, 10, 11, *Volvox globator*. See text.

12 to 19. DESMID. *Cosmarium botrytis* Propagation by division (Figs. 13 to 15) Sexual reproduction (Figs 16 to 19

20. DESMID. *Closterium lunula*

21. DIATOM. *Pinnularia viridis*

which are tiny proteid bodies, are found in the chromatophores, and during assimilation, starch granules are formed round them. The chromatophores are enclosed in transparent protoplasm, which appears under the microscope between the coloured area and the cell-wall. The pores in the cell-wall, already spoken of, are exits for fine threads of protoplasm, which gather on the outside of the cell and envelop it in a gelatinous sheath. Even groups of cells become enveloped in this way. Some forms exhibit a slow, creeping movement, while others fix themselves at one extremity to a substratum, allowing the free end to describe circles. Movement seems to have distinct relation to light. On a bright day one may secure certain species on the surface of a pool, but on a dull day one must seek them on or near the bottom. In the genus *Closterium* (Plate II., Fig. 20), which embraces crescent-shaped forms of singular beauty, a small vacuole occurs at each end of the cell, in which tiny granules of gypsum circle, as if chasing one another, in quite an energetic fashion.

Multiplication in the Desmids (Plate II., Figs. 12-19) is vegetative, or asexual, and sexual. The vegetative method is that of fission or division. The two valves of the cell-wall are pushed apart by the growing cell-contents, the nucleus divides into two, each daughter-nucleus to become the nucleus of a new individual. When the nuclear division is achieved, a septum or partition-wall is extended between the two valves, which shortly break apart, each retaining a layer of the septum. Of course, immediately on division, each of the parts appears like half a Desmid; but it is not long before the new cells assume the normal

shape. In this mode of multiplication one-half of the cell-wall of the new individual must needs be older than the other. In the sexual mode of increase, two cells are attracted to each other; they surround themselves with a protective gelatinous sheath. They either come into immediate contact or join by means of a short tube formed for the purpose. The cell-walls split at the constriction, allowing the cell-contents to escape. These contents may blend either in one of the cells or in the tube uniting the cells. The result is the formation of a zygote (Gr. *zygon*, a yoke). The zygote surrounds itself with a membrane, which is frequently studded with spines. It is not until the germination of the zygote is about to start that the nuclei of the conjugating cells fuse. In the course of germination, the membrane of the zygote bursts, and the contents divide into from two to eight cells, which gradually develop into adult Desmids.

The Desmids, then, display sex. Probably the asexual method of multiplication preponderates, but sex is in evidence; it may increase the vigour of the stock as well as numbers. But, as in the Diatoms, there is no differentiation of sex among the Desmids. However, there is somewhat of a distinction between the auxospore of the Diatom and the Desmid zygote; the former is a means of return to normal size, while the latter leads to an increase in numbers.

The Desmidiaceæ, on account of their peculiar sexual mode of reproduction, are classed, with other green fresh-water algæ, as Conjugatæ. The ZYGNEMACEÆ belong to the same class, and are no less interesting. This order includes the genus *Spirogyra*, of which there are

some seventy species. *Spirogyra* is found in floating masses in lakes and ponds; it favours still water, but I have found it in running burns in Scotland at an altitude of 1,000 feet. The floating masses, regarded from above, look like green scum. They are kept floating by means of bubbles of oxygen given off by the plants in the process of carbon-assimilation. The masses are composed of innumerable filaments of cells arranged end-to-end, the diameter of a single filament of one of the larger species not being more than $\frac{1}{100}$ inch. Yet, to the microscopist, this diameter is quite large, and his lenses enable him to observe the structure of the cells in much detail. The filaments are quite free and unattached, and the cells show the same characters throughout. In an examination of a single filament one cannot say which of the terminal cells is basal or apical. We have but to tease out two or three threads from a mass and examine them in water under the microscope to realize how singularly beautiful these components of despised pond scum really are. Each cell is seen to be cylindrical, generally longer than broad. The firm cell-wall, composed of cellulose, is lined on its inside with a layer of protoplasm, distinguished as the primordial utricle, and, if we are fortunate in our specimen, we shall see a process of circulation going on in this lining of protoplasm. A large, clear central space is apparent. This is the vacuole, not empty, but full of cell-sap. The nucleus in some of the larger species is suspended in the middle of the vacuole by strands of protoplasm, which anchor it to the chloroplast; in other species it is embedded in the primordial utricle. It is the chloroplasts which give the name to *Spirogyra*.

They are embedded in the primordial utricle, and occur in the form of spiral bands with irregular edges. The chlorophyll pigment renders them a beautiful, delicate green. The chloroplasts in a single cell vary in number, according to species, and even in the cells of a single species or a particular thread the number is not always constant; it ranges from one to ten. Pyrenoids (see p. 32), arranged in a single row, occur at intervals in the chloroplasts. From this description it will be observed that the *Spirogyra* cell is a well-organized structure.

Spirogyra is counted a multicellular plant, but we might reasonably regard each filament as a string of attached one-cell plants, for each cell is similar, and able to provide for its own needs. A filament may break and resolve itself into separate cells, each one being able to exist independently, and, in time, give rise to a new filament. Growth is achieved by cell-division. In this process the nucleus divides into two similar daughter-nuclei; a septum of cellulose—the organic substance of the cell-walls of the majority of plants—is gradually formed. This divides the cell into two daughter-cells, each one containing one of the daughter-nuclei. This, of course, spells vegetative growth, not reproduction.

In *Spirogyra* we have a plant which, normally, is entirely sexual in reproduction. The sexual process is most interesting. It happens in two ways: in the first the contents of two adjacent cells of a filament recede from the cell-walls and form rounded masses in the centres of their respective cells; then an opening is made in the septum separating the cells, and one of the rounded masses of cell-contents passes to the other,

blends with it, forming a zygote (see p. 34). The zygote secretes a membrane around itself, and passes through a resting-stage before germination. The cells which unite sexually are called "gametes" (Gr. *gamos*, marriage). The second mode of conjugation is the more frequent. Two filaments draw towards each other and lie side by side; very soon processes are formed at the sides of the cells of each thread, and unite as shown in Fig. 11, and Plate II., Figs. 1 and 2. In the meantime the cell-contents round off, as previously described. Ultimately the joined processes form a conducting-tube along which the gametes of one filament pass to those in the other. The gametes fuse and form zygotes. This process is often called the "ladder" type of conjugation, because the joined processes resemble the rungs of a ladder. The zygotes are freed from the cell-enclosures by the latter's decay, and become dispersed. They do not ordinarily germinate at once, but rest through the inclemency of winter; they can resist both cold and drought. Each zygote, on germination, gives rise to a new plant (Plate II., Fig. 3), which at first remains attached to a substratum by a colourless and attenuated base; but after a short period of growth the filament detaches itself from its anchorage, and floats freely, without displaying any definite base or apex.

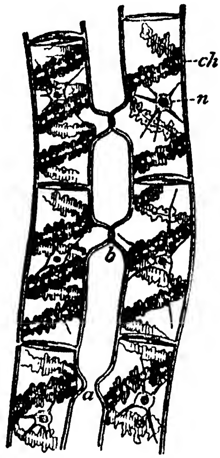


Fig. 11. — Spirogyra longata. × 350

Two filaments in conjugation. *a*, Early stage of formation of conjugating processes; *b*, processes in con-

Such is the life-cycle of *Spirogyra.* Let it be noted that the zygotes are formed from the fusion of gametes that, to outward appearance, are similar. Yet one of the gametes shows decided activity in passing out of its cell into the cell containing the other. To put it differently, one gamete stays at home and awaits the visit of the other; one is practically passive, the other active. The passive gamete may be likened to an ovule and the active gamete to the male element which fertilizes it. This idea of the differentiation of the sexes is confirmed in two ways: the chloroplast of the developing zygote is observed to be that of the passive gamete, while that of the active gamete is dissolved; and if the processes of conjugating cells are not exactly opposite, that put out by the female cell bends so that it may meet that proceeding from the male. And if the male gamete is prevented from reaching the female, the latter cell remains in its virginal state. In the absence of conjugation, unfertilized cells may, on occasion, form asexual resting-spores. So in *Spirogyra* we observe what we have not noticed in our previous subjects—differentiation of sex.

The genus *Zygnema* belongs to the same order and class as *Spirogyra.* The species of *Zygnema* are recognized by the two beautiful, star-shaped chloroplasts, separated by a space containing the nucleus, in each cell. The process of conjugation is similar to that in *Spirogyra,* with the exception that zygotes may be formed in the tubes connecting the conjugating cells. *Zygnema* should be looked for in all habitats favoured by *Spirogyra;* indeed, several species of each genus may occur in one floating mass.

Thus far in our study of the phenomena of sex we have considered the auxospore of the Diatoms and the zygote of the Desmids, both of which result from the fusion of sexually undifferentiated cells; but in *Spirogyra* we detect some signs of sexual difference in the conjugating cells. The Conjugatæ, however, are regarded as a side-line in evolution, and if we wish to study sex in its further advances, we must turn to plants of another class. We need not, however, go beyond the limits of the Algæ to discover new manifestations. Still confining ourselves to the Green Algæ (Chlorophyceæ), we shall find in the class CONFERVOIDEÆ some plants which will yield us some interesting evidence.

Before we proceed, we must familiarize ourselves with the term "thallus." This word is from the Greek *thallos*, a young shoot, and botanists apply it to the vegetative body of a plant which shows little or no differentiation into root, stem, or leaf. A *Spirogyra* filament is a thallus. All the plants we have hitherto considered are thallophytes, and we shall continue to treat of them until we have disposed of the Fungi, which are included among them.

The thallus of the Confervoideæ is always multicellular. The cells are usually arranged in a linear way, to form either branched or unbranched filaments. Yet the thallus does not always consist of a filament formed of a single row of cells, for it may be composed of cell-masses, or cells united into a leaf-like form. The green seaweed known as the Sea-Lettuce, or Green Laver (*Ulva latissima*), belongs to this class. Its thallus is composed of two layers of cells, and occurs in the form of good-sized wavy fronds. *Enteromorpha* is another

green seaweed common in the vicinity of the high-tide line. Its thallus is a branched tube, the wall being composed of a single layer of cells. The class embraces twelve families, but we shall confine our observations to two of them—the Ulotrichaceæ and the Œdogoniaceæ.

Ulothrix zonata occurs in ponds, but is more likely to be found in fresh-water ditches and brooks. The thallus in an unbranched, rather long filament composed of a single row of cells, which are about $\frac{1}{1000}$ inch in diameter. More than 1,000 cells may be found in one thread. The cells are about as long as broad. The filaments are usually found attached by a colourless basal cell to some object, such as a stone, in the water; the attachment cell may be branched in a rootlike fashion. But *Ulothrix* draws no food from its substratum, and can live free in the water; indeed, it is sometimes found in floating masses. Growth is effected by cross-division of the cells. Within each cell is a layer of protoplasm, the primordial utricle (see p. 35), containing an embedded nucleus; the bright green chloroplast, with its included pyrenoids, forms a broad band which, in short cells, is almost as broad as the cell length, but in longer cells appears as a belt in the middle; a large vacuole, filled with sap, occupies the interior of each cell.

Reproduction in *Ulothrix zonata* arises either asexually from zoospores, or sexually from gametes. Zoospores are usually larger than gametes. They are clearly distinguished by the possession of four lashes or cilia, by means of which they swim; gametes have two cilia. Zoospores may be formed, from one to four in number,

in any cell of a filament. In due time they are liberated through a side opening, formed by absorption, of the wall of the mother-cell. In addition to its four cilia, which rise from the transparent point of the pear-shaped body, each zoospore possesses a red pigment spot and a single chloroplast. Another feature is the "pulsating vacuole," a space in the cell which exhibits alternate expansions and contractions every few seconds. It has been demonstrated that zoospores are ineffectual in darkness, and Nature sees to it that they are liberated in the morning, so that they may have the benefit of daylight for their operations. On their escape, they swim about very actively, and might easily be mistaken for animals. But they object to too brilliant a light, and recede from it; moreover, as the end of their brief but merry state of activity approaches, before the descent of darkness, they show a strong disposition to avoid light. This disposition secures their dispersal, and so it happens that, after a few hours of activity, they become dispersed, and settle down on some object in the water on which they can germinate. In germination each zoospore produces a short process with which it attaches itself to its substratum, and gives rise to an ordinary *Ulothrix* filament. Thus we see that reproduction by means of zoospores is asexual.

The sexual gametes (see Fig. 12), which, as has been noted, are usually smaller than the asexual zoospores and have only two cilia, are produced in other cells of a filament; they may number from four to thirty-two per cell. Like the zoospores, they have one chloroplast, a red pigment-spot, and a pulsating vacuole. On liberation from the mother-cell they swim gaily in a swarm. It

usually chances that such a swarm will meet a similar swarm recently liberated from another cell; in this event marriage takes place with speed and minus the overtures of courtship. The meeting gametes pair, first becoming entangled by their cilia and spinning around in a merry dance. The two bodies gradually fuse, and in a few minutes the amorous partners have literally become one flesh. The fused gametes now constitute a spore, possessed with four cilia. These processes, however, are speedily withdrawn into the body of the spore, and this product of the marriage — really the zygote — settles down and becomes attached to some object in the water. It does not give rise to a new filament; it remains a one-cell organism which absorbs food, and consequently grows for a few weeks. Its contents become gradually denser and its wall thicker, until it is prepared and furnished for a period of rest. The rest is taken in summer, for *Ulothrix* takes its slack time in that season; it is most active through winter and spring. Growth is arrested in hot weather, and the sexually produced zygote is an ingenious device by means of which the plant tides over the period of uncongenial

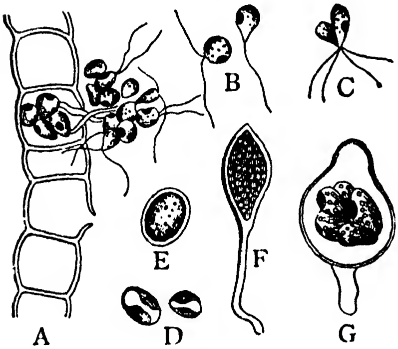


FIG. 12.—ULOTHRIX ZONATA.

A, Portion of filament, most of the cells being empty; gametes escaping from one cell; *B*, biciliate gametes; *C*, two gametes conjugating; *D*, young zygotes; *E*, ripe zygotes; *F*, zygote developing after period of rest; *G*, zygote forming zoospores.

heat and provides for the future of its kind, in spite of temporarily adverse conditions. When the zygotes germinate, in late autumn or winter, they first produce from two to fourteen cells, each of which may develop into a separate filament, or thallus, or they may develop zoospores that will ultimately settle down and grow into filaments.

We have outlined the general life-history of *Ulothrix zonata*, and I do not propose to adduce some further facts that, while interesting, are subsidiary, and would probably confuse the theme. It should, however, be mentioned that gametes which have been luckless in securing partners may germinate like zoospores—a clear case of parthenogenesis (Gr. *parthenos*, a virgin; *genesis*, production). Further emphasis must be laid on the fact that gametes from the same mother-cell do not conjugate; marriage can take place only among gametes from different cells. In this respect we have an instance of that cross-fertilization which is so frequent in the higher flowering plants.

Ulothrix, then, displays sexual reproduction by means of free-swimming gametes which are not sexually differentiated; we cannot say which is male or which is female. The sexual process is simple and primitive, yet it is obviously different in some details from that displayed in *Spirogyra* and the Conjugatæ in general. *Spirogyra* gametes are not ciliated; they do not break away and seek the freedom of the water, but they fuse within the shelter of a cell-wall.

Let us now examine our second example of the Confervoideæ, the genus *Œdogonium*. This genus includes numerous species, some of which are among the com-

monest of the green fresh-water Algæ. Unlike *Ulothrix*, they seem to prefer still water, such as occurs in ponds and water-butts; they frequently turn up in the standing water of aquaria attached to the glass. The thallus is an unbranched filament composed of a single row of cells. The basal cell is not so deeply pigmented with chlorophyll as the others; it is specialized into a disc of attachment, or a hold-fast, by which the thread clings to the surface of stones, plants, etc. The general appearance of a small female plant of *Œdogonium ciliatum*, under high magnification, is represented in Fig. 13. The apical cell in this species

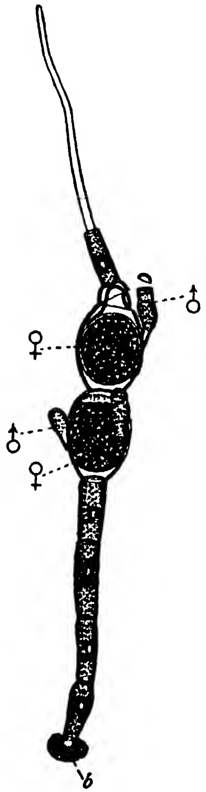


FIG. 13.—ŒDOGONIUM CILIATUM; SMALL FEMALE PLANT. × 166.

b, Attachment disc; ♀, ♀, oögonia, the upper one opening by a lid—it contains a fertilized egg-cell; the lower oögonium closed—it contains unfertilized egg-cell. ♂, ♂, dwarf males, the upper one opened so as to discharge a spermatozoid.

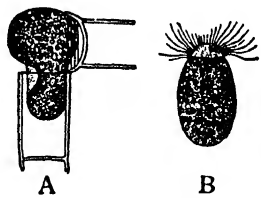


FIG. 14.—ŒDOGONIUM CILIATUM; ZOOSPORES. × 350.

A, Zoospore escaping from mother-cell; *B*, free zoospore with fringe of cilia.

is developed into a long hair. The ordinary cell has a wall of cellulose lined interiorly with the primordial utricle, a large chloroplast including some pyrenoids, a central vacuole containing cell sap, and a good-sized nucleus planted in the primordial utricle. The thallus grows in accompaniment with the increase of the ordinary cells by division. Asexual reproduction is effected by means of zoospores, as in *Ulothrix*, and any ordinary cell may develop into a single zoospore. In this development the cell-contents draw away from the cell-wall, become rounded off, and escape through a crack in the wall, as shown in Fig. 14, *A*. The resulting zoospore (Fig. 14, *B*) is a naked protoplasmic body, egg-shaped, transparent at the smaller end, around which there is a fringe of cilia, and containing a nucleus and chloroplast. On escape from the mother-cell, it swims about, ciliated end foremost, for a short time. It ultimately comes to rest, attaching itself by its colourless end to some object. The cilia rapidly disappear, the protoplasm secretes a cell-wall, the cell divides, and the zoospore gives rise to an ordinary filament or thallus.

We have seen that in *Ulothrix* sexual propagation arises from the fusion of gametes of similar size and sexually undifferentiated; they are both free-swimmers. In *Œdogonium* the male and female gametes are distinct, the former being smaller than the latter, while the male is active and the female passive. The term "gamete" is, strictly, applied only to similar sexual cells; where sex distinction is apparent the female cell is called the "egg" and the male the "spermatozoid." The egg of *Œdogonium* is formed from a special cell of the thallus,

which becomes swollen and barrel-shaped; this cell is termed the "oögonium" (Gr. *ōŏn*, an egg; *gonē*, generation). The egg is relatively large; it bears a colourless spot. In the wall of the oögonium opposite this spot an opening appears, and through this opening a little of the transparent protoplasm of the egg-cell is protruded. The egg-cell is now ready for fertilization. The spermatozoids essential for this vital business are developed in cells of the same or another thallus; they are like small zoospores. The special cells in which they are produced, usually two per cell, are termed "antheridia." A spermatozoid swims to the egg-cell, comes in contact with the protruded protoplasm, passes through the hole in the oögonium, and fuses with the passive egg. The fertilized egg secretes a cell-wall, and enters into a resting-state, in which it may remain for a few weeks. When it comes to germinate, the cell-wall is ruptured, and the contents, now enclosed in a delicate membrane, escape. Ordinarily the cell does not develop directly into a new plant; it divides into four cells, each of which becomes a zoospore similar to those produced asexually. All four zoospores escape, and, after fulfilling their roving commission, settle down and germinate. Thus four new plants are produced from one egg.

In some species of *Œdogonium* both sexes are represented in one filament; such are said to be monœcious. In others each sex is confined to a separate filament; they are diœcious. But many species have devised a rather more complicated sexual arrangement than that just described: the spermatozoids are produced from what are known as "dwarf males." This is the story: A series of small cells, much shorter than the

average cell of a thread, is formed by repeated divisions of parts of the thallus. The contents of these small cells are transformed into ciliated zoospores, which, although like ordinary zoospores in appearance, are smaller; in fact, they are intermediate in size between vegetatively produced zoospores and spermatozoids: because of their special function they have been named "androspores" (Gr. *aner*, *andros*, a man). The andro-

FIG. 15.—ŒDOGONIUM CILIATUM. × 350.
an, Escaping androspore; ♀, an oögonium.

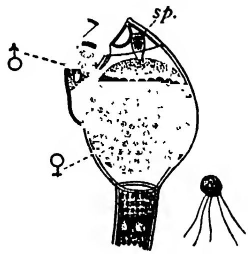


FIG. 16.—ŒDOGONIUM CILIATUM.
A, ♂, dwarf male plant from which a spermatozoid has been liberated; ♀, egg-cell which is being entered by the spermatozoid, *sp.*; *B*, a spermatozoid.

spores escape from the mother-cells in which they were formed (see Fig. 15), swim about for a brief period, and then settle on a female thallus, either upon the swollen oögonium or very near it. Thus settled, each androspore develops into a minute plant of a few cells. In one or more of these cells spermatozoids are developed to the number of two per cell; they eventually escape by the opening of a caplike lid as shown in Fig. 16, and

one of them enters the oögonium, fuses with the egg-cell, and so fertilizes it. Androspores are usually produced by the same thallus that bears oögonia.

We see from this brief survey of *Œdcgonium* that although it is an extremely simple plant as regards its thallus, it is well advanced in respect to sex. And within the ranks of the genus much resourcefulness is displayed. It is important for us to specially note the marked difference between the male spermatozoids and the egg-cells. The egg-cells are passive, relatively large, and well nourished; the spermatozoids are active, small, and furnished with just about enough nutrient stuff to serve their turn. The egg-cell needs much store to nourish that which is to be delivered from the innermost sanctuary of its womb; the spermatozoid requires only sufficient to maintain it during its brief activity—to support it in the sacred mission of bearing an element of Life into the sanctuary, an element that stimulates growth. For *Œdcgonium*, like all plants and animals, obeys the command, "Be fruitful and multiply, and replenish the earth"; it lives for posterity, and seeks the immortality of its kind.

The fertilization of *Œdcgonium*, as we shall see later, is in all essentials the same process as is involved in the highest plants. The likeness of its spermatozoids to zoospores is very suggestive; it seems to indicate that the former have evolved from the latter, that if we wish to discover the origin of the sexual spermatozoid we must look for it in the asexual zoospore.

But we have another inquiry to make. Embryologists assure us that the fertilized ovum, in its germination and development, tends, at least in part, to epitomize the

stages of the evolution of the life-form which it produces. Even so august an individual as the "lord of creation" began existence as a tiny fertilized ovum, and in his fœtal development exhibits indications of evolutionary stages which led up to the human genus. May not the life-history of such a plant as *Œdcgonium* throw some light on the problem of the origin and development of the vegetable kingdom? If we did not know from repeated observations that a tiny zoospore developed into a many-celled thallus fixed to a substratum, we could hardly imagine that a ciliated organism, so animal-like in its movements, could lead to such a result. But the fact remains. The thallus itself is but a local habitation for a series of living protoplasts, some of which may become zoospores, others egg-cells, others spermatozoids. Which is the more primitive, the active zoospore or the vegetative thallus? Must not the thallus have been originally developed from an active organism of which the zoospore is a specialized representative? Imagine a one-cell organism which hitherto lived a free existence, multiplying by fission, becoming fixed to some object in water; instead of the cells resulting from multiplication, separating, and swimming away, they remain attached in a single row. In such case you have a filament of cells. Any of the cells tend to revert to type. What wonder, then, that some of them become zoospores? Nor does it require a great stretch of the imagination to see in the spermatozoid a zoospore sexually adapted. The highly specialized orchid and the sturdy oak arise from microscopic egg-cells fertilized by a male cell; therein they seem to betray their lowly origin. But the zoospores and spermatozoids of *Œdo-*

gonium are somewhat more advanced than the zoospores and gametes of *Ulothrix*. It will be remembered that in *U. zonata* the zoospores possess but four cilia, while in *Œdogonium* they have numerous cilia arranged as a sort of fringe. The gametes of *Ulothrix* have only two cilia, and in this and other ways they seem to represent more nearly a type of organism closely connected with the ancient beginnings of plant-life on our earth.

Evolutionists are trying to discover organisms which are survivals of those from which both animals and plants had their origin; and there is a degree of agreement that minute flagellated protoplasmic organisms, which cannot be classed either as animal or vegetable, are the modern representatives of ancient life-forms that lived in water, and which have branched off into animals on the one hand and plants on the other. The zoospores and gametes of *Ulothrix* seem to indicate such an origin for many of the Algæ; but it is not easy to trace all green plants back to such an ancestry. But we must study one or two life-forms in order that we may see their bearing upon this interesting topic.

In Fig. 17 we have a drawing of a minute organism, *Euglena viridis*, which some of us may be disposed to regard as a modern survival of a stage in the series of stages which led up to some, if not all, green plants. *Euglena* is found in puddles, ditches, and ponds, sometimes in such numbers as to give the water a green tint. A single individual is not more than $\frac{1}{250}$ inch long. A goodly company can disport themselves as freely in a drop of water as a similar number of full-grown men in a large swimming-bath. A normal specimen is cigar-shaped, furnished with a single flagellum, by means of

which it propels itself through the water; also a red eye-spot, and a number of minute bodies coloured with chlorophyll. The cell membrane is elastic, enabling the organism to assume curious forms. It is not composed of cellulose. Within the body occur many minute plates of paramylum, a substance allied to starch. *Euglena viridis* multiplies either by longitudinal fission or by the formation of cysts, within which a single cell divides into two, four, or even more individuals. In the matter of nutrition it seems that *Euglena* can ingest tiny particles of food, indicating an animal mode of feeding, and also assimilate carbon dioxide and form carbon compounds, a power indicated by the chloroplasts and the paramylum bodies; thus, it shows both animal and plant characters. The absence of cellulose in the cell-membrane is noteworthy.

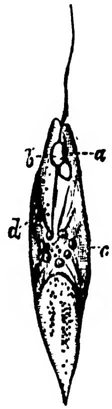


FIG. 17.—EUGLENA VIRIDIS (EHRB.). HIGHLY MAGNIFIED.

c, paramylum granules; *d*, chromatophores.

May we not regard *Euglena* as a by-product of evolution, suggesting an ancestral stage in the rise of certain green plants? We do not suggest for a moment that this organism is one which itself anciently led on to higher forms; all we venture to submit is that it indicates a remote development in the course of which primitive monads, through the production of chlorophyll, gradually assumed plant characters. Perhaps in *Euglena* the animal and plant characters are fairly evenly balanced, but we can imagine a series of developments leading to

the preponderance of plant characters until ultimately all traces of a seeming animal nature disappeared. The ciliated zoospores of *Ulothrix* and other Algæ give rise to a plant thallus. With such a fact before us, we should hesitate before declining to believe that a large number of, if not all, green plants have evolved, by easy stages in the course of ages, from a one-cell flagellated ancestry. Such scepticism becomes the more difficult when we come to consider the egg-cells and spermatozoids of higher plants and the elaborate structures resulting from their fusion. The development of an individual plant from a fertilized egg-cell, going on, as one might say, before one's eyes, may be taken as a recapitulation—at least, in outline—of the stages of development which slowly led up to the evolution of the individual in a distant past.

In the evolution of distinctly plant forms we may assume that the elaboration of a cellulose cell-wall was an important advance—one that is suggested by such a type as *Chlamydomonas* (Fig. 18), which may properly be associated with the Volvoceæ, a family of the Green Algæ. Specimens of this minute one-cell plant occur in stagnant water, such as contained in pools and ditches. They seem to be most plentiful towards the end of spring and in the autumn. On examining a few specimens under a high power of the microscope, we find that the cell-contents are enclosed in a membrane of cellulose—a fact readily proven by a chemical test. We might conclude, at first sight, that the cell was uniformly green; but close observation discloses the fact that the green colour (chlorophyll) is confined to a cup-shaped chloroplast, containing a mass of clear proto-

plasm, within which a single nucleus resides. The chloroplast is thicker at the posterior end—the bottom of the cup—where it encloses a spherical pyrenoid. The fore-part of the cell is colourless, being occupied by clear protoplasm, in which one or two vacuoles may be seen appearing and disappearing. A red or brownish pigment, or "eye" spot, is also visible at one side of the body towards the front. This tiny one-cell plant swims in a jerky fashion, rotating on its long axis as it proceeds, its direction being towards a light of moderate intensity; and it is suggested that the pigment spot has something to do with the plant's sensitiveness to light. But how is it enabled to swim? If we watch a cell that has come to rest, we may be able to see that a pair of flagella issue from the colourless protoplasm to the fore. These exceedingly fine lashes are more easily observed when the cell is stained, say, by iodine. It is by lashing the water with its two flagella that *Chlamydomonas* swims.

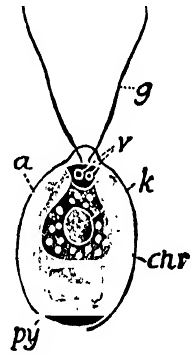


FIG. 18. — CHLAMYDOMONAS ANGULOSA. HIGHLY MAGNIFIED. (*STRASSBURGER.*)
g, Cilia; *v*, vacuole; *chr*, chloroplast; *k*, nucleus; *a*, eye-spot; *py*, pyrenoid.

Animal-like as this organism is in its movements, it is certainly a plant. It has no mouth; it cannot ingest solid food; it must feed upon the products of carbon assimilation and salts in solution, all its requirements reaching it in solution through its permeable wall of cellulose.

Even in so small a plant as *Chlamydomonas*, both asexual and sexual modes of reproduction are apparent.

In the asexual mode the flagella are first drawn into the body; then the protoplast divides into two masses. Each of these masses may secrete a cell-wall and produce flagella, or, more frequently, each mass divides into two, so that four daughter-cells are produced within the wall of the parent cell. All four cells become perfect individuals, escape from the membrane enclosing them, and enter upon an active life. There are several species of *Chlamydomonas*, and it seems that in nearly all sexual reproduction is due to the conjugation of equal gametes, which fuse to form a zygote, the latter giving rise to several individuals. But in one species large and small gametes are produced, indicating differentiation of sex.

Chlamydomonas, then, represents a distinct advance in the evolution of plant forms. In *Euglena* we saw a suggestion of an organism adopting plant characters, but we noted the absence of cellulose, and we discovered no evidence of sex. In *Chlamydomonas* a cellulose wall appears, nutrition is wholly plant-like, and reproduction is both asexual and sexual.

The so-called "Red-snow," which occurs on Alpine snowfields in bright crimson patches, is due to vast numbers of a *Chlamydomonas*-like Alga, which has been variously named *Sphærella nivalis*, *Hæmatococcus pluvialis*, and *Chlamydomonas nivalis*. The red colour is due to a pigment—hæmatochrome—which masks the green chlorophyll of the cell. The pigment may be a species of light filter, allowing only such rays to pass as will be useful in maintaining the vitality of the Alga in its exposed situation. While the snow upon which the tiny plants lie is frozen the cells are not motile, but

when summer heat causes a thaw, they grow and divide, the daughter-cells escape and swim in the snow-water by means of flagella, each cell being furnished with a pair of these motile appendages. So in "Red-snow," we have a *Chlamydomonas* adapted to arctic conditions. It is non-motile, and in a resting condition during the winter; the summer sun awakes it into activity, and each cell gives birth to a number of flagellated motile cells. This power of adaptation is highly instructive, for it indicates how a motile aquatic organism may become adapted to terrestrial conditions, and assume a form and habit to meet their requirements.

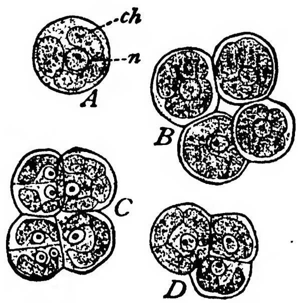


FIG. 19.—PLEUROCOCCUS VULGARIS. × 540.

A, An ordinary cell; *ch*, chloroplast; *n*, nucleus; *B*, four cells produced by division and separating; *C*, cells grouped in contact, the two to the left having just divided; *D*, tetrahedral group.

Further evidence of an approach of an aquatic one-cell plant towards terrestrial existence is furnished by the green Alga *Pleurococcus vulgaris*. This occurs in vast numbers on wooden palings, trunks of trees, and wet walls, forming a very familiar green powdery covering, particularly in situations not reached by the direct rays of the sun. *Pleurococcus* flourishes best in damp weather. Fig. 19 illustrates the story of this plant. The cell consists of protoplasm, with a single nucleus, and a number of very small chloroplasts, and is invested by a thin wall of cellulose. The cells occur singly or in little groups. When they cohere, the sides in touch are slightly flattened by the pressure.

In very dry weather they seem to rest, and are easily dispersed by wind; but in damp conditions they show much activity in reproduction by division. One cell divides into two, repeated divisions follow, and the resulting individuals may either cohere in groups for a time, or separate soon after formation. Each cell is perfectly independent.

We have yet much to settle in regard to the life-history of *Pleurococcus*, and future observations will probably confirm indications that, in addition to the simple mode of reproduction by division, motile zoospores and sexual cells are produced; moreover, that filaments of cells occur. Thus, the life-cycle of this Alga may be much more complicated than has hitherto been supposed. It is customary among evolutionists to regard *Pleurococcus* and its allies as the modern representatives of a stage of development intermediate between the *Chlamydomonas* stage and several higher forms. The vegetative *Pleurococcus* cell may safely be regarded as derived from a cell of the *Chlamydomonas* type which lost its motile flagella, and became invested in a continuous membrane of cellulose in adaptation to terrestrial conditions. It would not be at all surprising to find such cells producing motile cells in an aquatic environment. But the developments leading to higher plants would most probably take place in water. We may imagine a *Chlamydomonas* type of cell losing motility and coming to rest. It adheres by a mucilaginous secretion to some object, grows, and divides. The daughter-cells do not disperse, but remain in contact, either in rows, so forming filaments, or in groups, due to cell division in two directions, thus producing a plate-

like thallus. Thinking in this way, we have little trouble in seeing how several forms of thallus might diverge from the Pleurococcid cell. We must not be forgetful of the fact that Nature sometimes produces startling mutations, and makes curious jumps; there is a tendency to "sport," to kick over the traces of ancestral limitations, and to adventure in new directions. A million Pleurococcid cells might behave according to ancestral traditions, and their progeny might, through an æon, adhere most rigorously to the old ways; but a half-dozen cells might become restive under a mysterious inexplicable stimulus, and start a new line of evolution.

From a simple filamentous thallus, arising in the manner just suggested, we can follow later developments. At first almost any of the cells would produce motile zoospores, by a partial reversion to ancestral type, or the filament itself might break up into its component cells, setting them free to develop new threads by simple division. Later would follow the production of equal gametes, which we may regard as specialized zoospores, both gametes being set free from their mother-cells, and motile; and, later still, further specialization would lead to formation of passive egg-cells and active spermatozoids. It is along some such line as here suggested that plants like *Ulothrix* and *Œdogonium* have probably evolved. These types, in their turns, represent intermediate phases leading upwards to the Liverworts and still more advanced land-plants.

Thus, we have followed a possible line of evolution from the *Chlamydomonas* type of cell, through the Pleurococcid form, to the Confervoid Algæ, and, later, to land-plants. The significance of the facts and sug-

gestions we have adduced will be more fully appreciated when we come to deal with the Mosses, Ferns, and more advanced alliances. But we have yet to notice an interesting divergent line of development, from a *Chlamydomonas* origin, which does not involve a Pleurococcid stage.

Gonium pectorale (Fig. 20) is a little plant found on the mud of stagnant pools and ponds. The actual size may be imagined from the fact that our diagram represents the plant magnified 300 diameters. It consists of a colony of sixteen adherent cells arranged in the form of a plate, or rosette. Each cell is furnished with a pair of flagella, a red pigment spot, and chlorophyll. The cells are attached to each other by protoplasmic substance, and the colony is invested by a gelatinous membrane, through which the flagella penetrate on one side of the plate. The flagella move in unison, as if controlled by a master impulse, and propel the colony through the water. The plant revolves in the water in a wheel-like fashion, and it frequently happens that the observer sees only the edge of the plate. *Gonium* obeys the command to "multiply and replenish the earth" in two ways. The first mode of reproduction is asexual. All the cells divide simultaneously, there being four successive divisions in each cell, the result being sixteen aggregates of sixteen cells each. These aggregates of newly formed cells break away from the

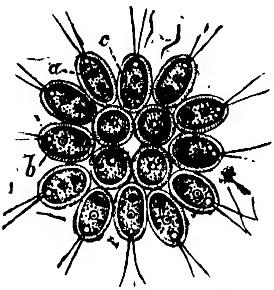


FIG. 20.—GONIUM PECTORALE. × 300.
Colony seen from flat side. *a*, Nucleus; *b*, contractile vacuole; *c*, pyrenoid.

parent colony, each becoming an independent *Gonium.* Sexual reproduction also occurs; some of the adult cells break away from the colony, come to rest, then divide into eight gametes, each having two flagella. The gametes are of equal size, so that they give no indication of sex-differentiation. They conjugate in pairs, form zygotes, which in due season give rise to new colonies.

Gonium is practically a colony of cells of the *Chlamydomonas* type; it represents an attempt to produce a multicellular plant by the grouping of hitherto independent cells. In *Pandorina* we have a plant founded on similar lines, but showing an advance on *Gonium.* *Pandorina,* also a very small plant, is found in ponds; it is a colony of sixteen wedge-shaped cells forming a sphere. Each cell has chlorophyll, a red pigment spot, and a pair of flagella, and the colony is invested in a gelatinous membrane. The plant swims with a rolling motion. Daughter-colonies are produced asexually as in *Gonium.* Colonies of gametes are also formed, usually eight-celled; the gametes acquire flagella, escape from the membrane in which they are originally invested, swim about, and ultimately conjugate. But it happens that a number of parent colonies of various sizes produce gametes simultaneously. The resulting gametes are of various sizes, and it is said that the largest gametes never fuse in conjugation; they become almost passive, and gametes of small size actively seek them out and pair with them. But, with the omission of these large, almost passive gametes, others of equal or unequal size conjugate freely. Thus, we have in *Pandorina* a most interesting illustration of the development of sex-differentiation, for within the life-cycle of a single species

we have the conjugation of sexually undifferentiated gametes, and also the occasional production of approaches to egg-cells and spermatozoids. The sexual distinction is not pronounced, but it is sufficiently marked to indicate that full distinction arose from such an intermediate stage by the elimination of intermediate sizes of gametes, only the largest remaining and becoming passive egg-cells full of nutriment, while the smallest became specialized into active spermatozoids.

Within the family Volvoceæ, which includes *Gonium* and *Pandorina*, we have a complete series of forms illustrating the evolution of sex. One would fain refer to a number of interesting and instructive types, but as our space is limited we must be content with a short description of a form in which sex distinction is consummated. The little whirling globes of *Volvox globator*, swimming majestically in a "live-cell" under the microscope, are always the wonder and admiration of the observer. The life-cycle of this remarkable plant is ably illustrated in Plate II., Figs. 8-11. *Volvox* is found in ponds; it seems to be a very delicate plant, being extremely sensitive to changes of temperature. It is visible to the naked eye, as it averages about a millimetre ($\frac{1}{25}$ inch) in diameter. A person seeing this plant for the first time might be forgiven for thinking it an animal, and would certainly be astounded when told that it was a plant composed of a colony of cells ranging from 15,000 to 22,000 in number. The individual cells are of the *Chlamydomonas* type; they are united to each other by strands of protoplasm and form a sphere, the bases of the cells pointing inwards, and the bi-flagellated apices outwards. The plant swims, in dignified rota-

tions, by means of the flagella, which lash the water in concert and with a regularity of stroke that might well be the envy of a University crew. *Volvox aurea* is another species of the genus; it is smaller than *V. globator*, the number of cells varying from 200 to about 4,000.

A notable feature of *Volvox* is the fact that certain cells appear to be told off for special work. Thus, in *Gonium*, as we have noticed, each cell of the colony is capable of producing a daughter-colony, but out of the thousands of cells in the *Volvox* colony only about eight are allowed to engage in this asexual reproduction. These few cells are generally in the hinder region of the parent colony, and they soon display a tendency towards their function. They grow larger than the ordinary cells, and, as a result of repeated division, develop into daughter-colonies, appearing as so many small spheres within the parent sphere. They ultimately rupture the wall of the latter, escape, and grow to adult size.

Special cells for sexual reproduction arise in certain colonies. In their early stage they closely resemble the cells told off for asexual increase as already described, but they are more numerous. Later they become clearly differentiated into male and female, the male being called "androgonidia" (Gr. *anēr*, a man; *gonē*, generation), the female *gynogonidia* (Gr. *gynē*, a female, and *gonē*). In *Volvox globator* there are from two to five male cells and from twenty to forty female cells. The female cell, while still in the wall of the colony, becomes flask-shaped, but later it makes its way into the inside of the colony and becomes a rounded egg-cell. Within the male cell a bundle of yellow, spindle-shaped, flagel-

lated spermatozoids appears; these male elements, which are highly specialized, number from 64 to 128. At the proper moment they escape from their parent cell and swarm round the egg-cells. One spermatozoid, more fortunate than its brethren, fuses with an egg-cell, which is thus fertilized. After fertilization the egg-cell, now a zygote, secretes two membranes about itself for its protection; it also changes from green to yellow, and rests for a considerable time before germination. The zygote is a convenient resting-stage, enabling *Volvox* to tide over the uncongenial winter months. A single adult colony is developed from each zygote, and even before the embryo leaves the parent cell there is some evidence of certain cells being marked off for asexual reproduction. Several asexual generations may occur prior to the appearance of colonies bearing sexual cells.

Thus the small but majestic *Volvox* displays remarkable development. The great majority of its cells are purely vegetative, and only a few are marked off either for asexual or sexual reproduction. Asexual increase occurs for a few generations under congenial conditions, while the sex activity is preliminary to a resting-stage when the conditions are anything but congenial to so delicate a plant. We may opine that constant asexual reproduction would tend to exhaustion, and that the occurrence of an occasional sexual generation leads to the stimulation and renewal of vitality. The egg-cell is relatively large, wellnourished, and passive; the male elements are highly specialized, active, and seek out the egg-cells. The spermatozoids are produced in goodly numbers, and as only one fuses with an egg-cell, many of them are wasted. This, however, is an instance of

Nature's purposeful prodigality whereby there is insurance against risks and chances. Were only one spermatozoid formed for one egg-cell, it might miss its mark; but seeing that the proportion of male elements to egg-cells averages about sixteen to one, the risk of failure to fertilize is negligible. The male elements are poorly nourished; they are creatures of an hour, specialized vehicles of a mysterious stimulus, eager, excited, even feverish in their passion for union with their natural mates; sufficient nutrient material within their slender bodies to sustain them in their mission is all they need. They seem to have meat to eat that we know not of, for it is not by strength of body but by some elusive power of which we know nothing that they do their work. The egg-cell is the potential mother, furnished by Nature with abundant substance for the building up of that sacred thing which it is called to bear. One might almost aver that the egg-cell, or mother-element, is the builder of the body, while the male element is the vehicle of the soul of the as yet unborn colony.

In *Gonium*, *Pandorina*, and *Volvox* we have seen three stages in the evolution of colonial aggregates of cells of the *Chlamydomonas* type. *Volvox* is the most specialized form, but there are intermediate forms that we have not described that fill in the gaps and make a complete series, illustrating an attempt of Nature to evolve higher plants along the lines of spherical colonies. The attempt culminated in *Volvox*. The whole series stands as a side-line of evolution. *Volvox* leads nowhere; it is a cul-de-sac. One could hardly expect the attempt to succeed beyond such a stage, for the *Volvox* colony is delicate, easily ruptured, and liable to collapse.

We shall conclude this chapter with a reference to an order of Algæ whose affinities are obscure. The SIPHONEÆ, to which we refer, are marked off from other Algæ by the nature of their thallus, which, in spite of often being much branched, is tubular, and not composed of cells enclosed within their several cell-walls. The tube is a product of a single cell, and its membrane encloses a continuous protoplasmic body, containing many chloroplasts and nuclei. Compartments, formed by transverse septa, occur in the more complex forms. Many species, such as those belonging to the genus *Caulerpa*, are marine. The species of this genus are much varied in form; they occur in tropical and subtropical seas, often growing in great masses or beds. No matter how varied the forms are, or how branched they may be, the thallus always consists of an uninterrupted tube. These marine plants might be accused of mimicking such land plants as Cactuses, Ferns, Horsetails, Mosses, etc. Multiplication seems to be due to parts of the thallus breaking away and developing into new plants; no sexual cells have as yet been observed in any forms.

Botrydium granulatum, another member of the Siphoneæ, exhibits great capacity of adaptation to changes of conditions. This little plant occurs on the moist margins of ditches and ponds, especially on loamy soil. It has a green, balloon-like shoot, never more than about $\frac{1}{6}$ inch in diameter, which appears above ground, and a colourless, branched, rootlike portion that grows into the soil. It is a one-cell plant, whose cell-membrane encloses a continuous cavity, which is not only evident in the upper part, but is also

continued into the tubular rootlike processes. The membrane is thinly lined on its inner side with much-nucleated protoplasm, and the green of the shoot portion is due to the presence of chloroplasts arranged in a netlike manner. Under favourable land conditions *Botrydium* reproduces principally by buds which arise from the green portion, put out root processes, grow to full size, and become separated from the parent plant. This method of increase is not well suited to aquatic conditions, so if *Botrydium* is submerged, it meets the problem of reproduction by breaking up into a number of zoospores, each possessing two chloroplasts and a flagellum. These zoospores drift towards, or seek out, damp soil at the edge of the water, and develop into normal plants; but if they cannot reach soil, in due course they enter upon a resting-stage, in which they remain until they find suitable conditions for germination. But this adaptable little plant can also meet dry conditions. Lack of moisture, together with strong sunlight, causes the protoplasm of *Botrydium* to break up and the portions to round off, forming a number of round cells, each invested in a cell-wall. When these cells become covered with water, each one breaks up into cigar-shaped gametes furnished with two flagella. These gametes conjugate in pairs and form zygotes, from which new plants germinate. But if the cells, which break up into gametes in water, reach damp soil, they at once germinate and become new plants. The gamete formation, then, is an adaptation to aquatic conditions.

But within the range of the Siphoneæ the genus *Vaucheria* exhibits the most remarkable sex-differentia-

tion. Details of *Vaucheria sessilis* are admirably illustrated in Plate II., Figs. 4-7. This plant, in common with others of its kind, is extremely simple in its vegetative parts. The thallus consists of an irregularly branched, tubular green filament, the cell-wall being of cellulose, and the protoplasm, with which it is lined interiorly, includes countless nuclei and chloroplasts. The filament is attached to a substratum by a branched, colourless, root process. The filaments are visible to the naked eye; they form a sort of loose green felt on moist soil, and not infrequently occur on the soil of plant-pots in greenhouses. Species of *Vaucheria* also grow in salt and fresh water. The growth of the filaments is apical, and the protoplasm at the growing points of the stem and branches is always colourless.

Asexual reproduction by zoospores takes place mostly in water, or when the conditions are very moist. The zoospore is formed, at the end of a branch, from a portion of the protoplasm, which accumulates there and becomes dense. The cell-wall at this point bulges into a club-like form, and that portion becomes divided from the branch by the growth of a septum. Thus, a separate cell is formed; it is dignified by the term "zoosporangium." Only one zoospore is formed in this cell, but it is notable for possessing many nuclei and chloroplasts. The zoospore eventually escapes from the apex of the cell through a narrow opening. As the opening is narrower than the bulk of the zoospore, the latter is compelled to change its form as it forces its way through. Sometimes it breaks into two portions in the effort to escape, in which event each portion becomes a zoospore. The zoospores usually emerge in the morning. They

possess numerous cilia, enabling them to swim; but they are active for a very short time, and only in a sluggish fashion. They soon come to rest and germinate, a filament being produced which sends a root process into the soil and forms branches rapidly.

Asexual reproduction by zoospores is the normal order of things with *Vaucheria,* so long as water is plentiful and the season is favourable. But if water tends towards scarcity, the plant anticipates drought, and prepares to tide over adverse conditions by forming fertilized egg-cells. The story is illustrated in Plate II. Two organs are formed, the antheridium (*x*) and the oögonium (*o*). In the antheridium, which becomes separated from the process in which it is developed by a septum, a number of minute flagellated spermatozoids (*z*) appear; while a passive egg-cell, large and well nourished, is formed in the oögonium. The spermatozoids duly escape from the antheridium, and swarm round the egg-cell, finding their way into the oögonium through an aperture. One individual, more fortunate than the rest, fuses with the egg-cell and fertilizes it. The fertilized egg-cell secretes a stout cell-wall around itself, and is now prepared to endure even a prolonged time of drought. It germinates when conditions are favourable, and forthwith produces an ordinary thallus, which is not long in forming zoospores, and continues to form them for several generations.

Thus *Vaucheria,* which may be called a non-cellular Alga, is remarkable in two particulars: it is very simple in its vegetative arrangements, yet, in spite of that simplicity, it has developed sex-differentiation of a high order. As we have already indicated, the Siphoneæ do

not show any very distinct affinities with other plants; they must, therefore, be regarded as another side-line in the evolutionary development of plant-forms. *Vaucheria*, however, seems to lead to the Fungi, which fall to be discussed in a later chapter.

CHAPTER III

SEAWEEDS

ALL Seaweeds are Algæ, but all Algæ are not seaweeds. We have already described several forms of Green Algæ that occur in fresh water, and, as a matter of fact, the great majority of Green Algæ are fresh-water forms.

Even a casual observer of Seaweeds will be struck by the variation of their colours, and it happens that colour is quite a good basis for classification. This colour basis establishes three main groups of Algæ:

1. THE GREEN ALGÆ = *Chlorophyceæ.*
2. THE BROWN ALGÆ = *Phæophyceæ.*
3. THE RED ALGÆ = *Rhodophyceæ.*

Arrangement according to structure and development practically coincides with this colour classification. The Brown and Red forms are mainly marine, and, doubtless, their peculiarities of structure and colour are due to their environment. It also happens that the colours of Seaweeds have a definite relation to the depth of the water in which they occur. While there are numerous exceptions, the general rule is that dense growths of Green Algæ, among which species of *Enteromorpha* (p. 39) and *Vaucheria* (p. 65) are conspicuous, occur near the shore, where they are covered by the water only at high-tide. Brown forms occupy the region between tide-marks and, in the same zone, some red

forms, which, however, are sheltered by the brown, are also found. At and beyond low-water mark we find a vigorous growth of the brown Kelps, or Tangles, which also shelter red species. This belt is known as the "Laminarian zone." Beyond this zone, in the greater depths, unsheltered red forms occur. But seaweeds can flourish only within a limited depth; they become rarer as the depth increases from 20 to 50 fathoms, and below the 50-fathom line they are exceptional.

If brown and red Seaweeds are soaked in fresh water, their brown and red pigments are dissolved, but the green pigment, chlorophyll, remains. It is, then. demonstrable that all Seaweeds contain chlorophyll, which is used in the business of carbon assimilation, the necessary carbon dioxide being held in solution by the water in which the Algæ live. The chloroplasts are simply masked by the brown or red pigment, and it becomes apparent that the pigments have a definite relation to light; they are, indeed, light-filters, which modify sunlight as it penetrates the water, and accommodate it to the requirements of the chloroplasts. It is contended by some authorities that the pigments increase the susceptibility of the chloroplasts to rays of light that are most efficient in carbon assimilation. If we pass a beam of white light through a prism, and project it on a screen, we see that rainbow effect known as a "spectrum." The colours of a rainbow appear upon the screen. First, we have red, which shades off into orange, yellow, green, blue, indigo, and violet; and it is known that certain invisible rays occur at either end of the spectrum. At the red end we have rays

which are capable of raising the temperature of a body: these are dark heat-rays. At the violet end we have the ultra-violet rays, which produce a distinct chemical effect upon a photographic plate. Now, it is known that the red and yellow rays are absorbed by chlorophyll, and we naturally conclude that they have all-important effects in carbon assimilation. It is also known that an excess of blue rays is hostile to green plants. The water in which the Seaweeds grow also acts as a light-filter; it not only reduces the quantity of the sunlight in proportion to its depths, but it also affects its quality. The very rays that are most efficient in carbon assimilation are the first to be intercepted by the water, and the green and harmful blue rays penetrate to greater depths. It would seem, then, that the use of the brown and red pigments of Seaweeds is either to heighten the susceptibility of the chloroplasts to red and yellow rays, or to screen them from the excess of blue rays; the weight of probability is in favour of the latter contention. In Nature "nothing walks with aimless feet." The pigments of Seaweeds are not the products of creative caprice, but perform a definite use. The peculiar pigment of the brown Algæ accommodates them to the light conditions of the zone they occupy, while the red pigment of the red Algæ accommodates them to the light conditions of deeper water. It is significant that when red species occur in the brown zone, they are usually sheltered by brown species.

The ubiquity of Algæ on the world's coasts is remarkable. Seaweeds occur from the Arctic regions to the Tropics, and from the Tropics to the Antarctic; but there is diversity of species in relation to climate and

other environmental conditions. Over 250 species occur on the coasts of the Arctic Sea, nearly 900 are found in the West Indies, while Australia has over 1,100 species.

In regard to the sites on which Algæ grow, it is noticeable that they favour a rocky shore with an abundance of rock-pools, the water of which is renewed at every tide. Such a shore is literally covered with Seaweeds, in marked contrast to stretches of sand, on which few species occur, and only such as are furnished with long threadlike rootlets, by means of which they can get an anchorage in the sand. It should be remarked that Seaweeds have no true roots. The rootlike processes by which they attach themselves to rocks or sand have no relation to nutrition; they are merely holdfasts enabling the thalli to anchor themselves, and thus retain a position in the water most suitable to their needs. All necessary food elements are found in solution in the water, and are absorbed through the permeable cell-walls of the thallus, or "frond," as it is often termed. Seaweeds are subjected to the movements of water, and are well adapted thereto. Species which thrive where movement is gentle—for instance, in a rock-pool—would have a poor chance in surf. But there are species which love the surf, and are well accommodated to its relentless movement by the possession of strong holdfasts, flexible stalks, and blades that swing with the water.

The careful observer will notice that not only are Seaweeds zoned according to colour, but also that different species occur within the limits of a colour zone, forming zones within zones. Thus, on a typical West of Scotland rocky shore we find in the green zone, near high-

water mark, an abundance of the tubular, wavy, pale green *Enteromorpha intestinalis,* varying from one to many inches in length, and fading through yellow to white in decay. This Alga is well suited to brackish water, and is sometimes found in inland waters. In the same zone we also get the Sea Lettuce (*Ulva lactuca*), light green in colour, becoming yellowish in decay. The delicate, nearly transparent thallus of this plant, when mature, is flat, ribless, wavy, and somewhat rounded at its margin. It is from 3 to 6 inches long, and broad. This mature form arises from the rupture

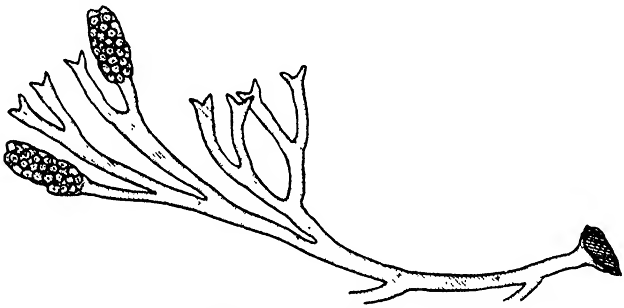


FIG. 21.—HOLY-WRACK (PELVETIA CANALICULATA).

of a puckered, inflated, saclike thallus—the immature from. Descending to the zone of the brown Seaweeds, we first encounter the Holy-Wrack (*Pelvetia canaliculata*), which is depicted in Fig. 21. The thallus of this species is from 2 to 6 inches long, olive-brown or -yellow in colour, and it is repeatedly forked in its mode of branching. Every part is grooved on one side; hence the name "Channelled-Wrack." It is said that cattle are fond of this plant, and browse on it in winter when it is left exposed by the tide. It is sometimes given as a medicine to sheep and cattle. *Pelvetia* grows in bushy

tufts, and forms a narrow band, varying in width in accordance with the slope of the shore, immediately below high-water mark. A little lower we may find

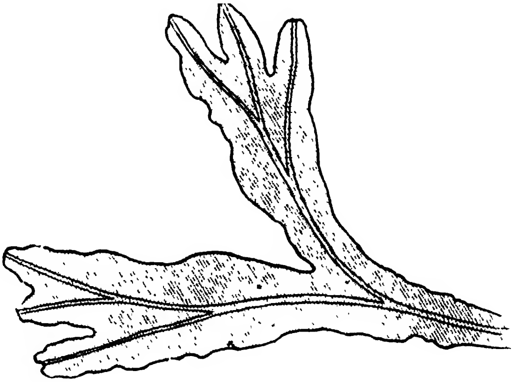


FIG. 22.—FLAT-WRACK (FUCUS PLATYCARPUS).

Flat-Wrack (*Fucus platycarpus*, Fig. 22), which has a thallus about 6 inches long, or, in its absence, the next species in the descending series will be the exceedingly

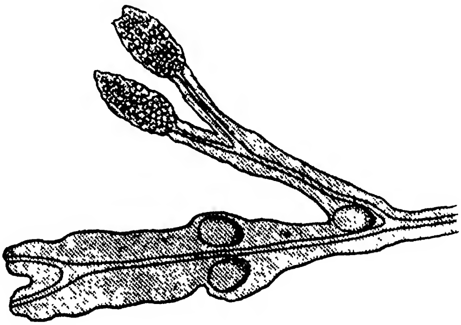


FIG. 23.—BLADDER-WRACK (FUCUS VESICULOSUS).

common Bladder-Wrack (*Fucus vesiculosus*, Fig. 23). This species hardly needs description. It is easily recognized by its good-sized, round air-vessels, swellings

in the branches, which occur mostly in pairs in various parts of the fronds. The length varies from 2 or 3 inches to several feet. It is obvious that the air-vessels serve as floats. We cross the zone of Bladder-Wrack, and at

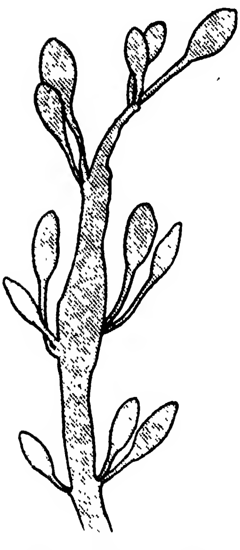


Fig. 24.—Knobbed-Wrack (Ascophyllum nodosum).

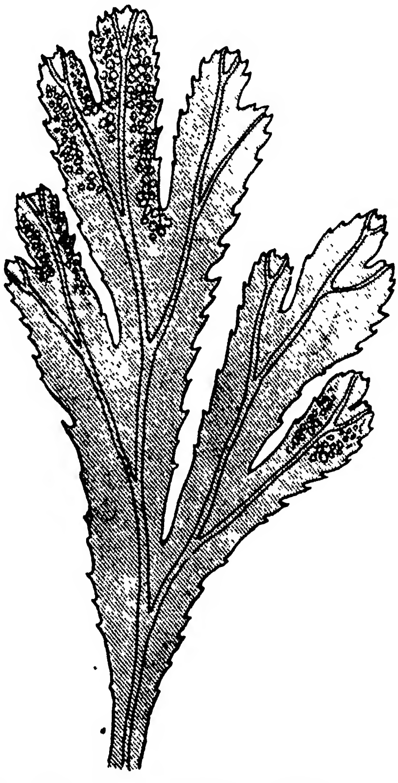


Fig. 25.—Notched-Wrack (Fucus serratus).

once encounter Knobbed-Wrack (*Ascophyllum nodosum*, Fig. 24), a tough, leathery, olive-green species, varying from 2 to 6 feet in length, the thallus consisting of narrow, branching straps, several of which arise from the one base. It bears large, oblong air-vessels, due to

inflations in the branches, and occurs between half-tide level and high-water mark. Associated with Knobbed-Wrack, but extending beyond it to below half-tide level, is Notched-Wrack (*Fucus serratus*, Fig. 25). This species has a thallus, with a midrib, and which forks repeatedly in its branching. The margins are invariably toothed like a saw—*i.e.*, serrate. The colour is dark olive-green, and the length varies from 2 to 6 feet. At low-water mark, and considerably beyond, we discover the big Tangles, with their long, flat fronds. The region in which this sea-forest thrives is called the Laminarian Zone.

Seeing that animals are fundamentally dependent upon plants for their nutrition, it is plain that Seaweeds are all-important as a food basis for marine animals. Even in the vast ocean regions where ordinary Seaweeds do not occur, there is a floating plankton of very minute plants, which are, perhaps, even more than the grains of sand on the seashore in number. Diatoms are the most important members of this floating flora in the colder seas of the north and south, and they are found mixed with tiny *Peridineæ* in the temperate seas. They have a much wider range than this note indicates. The *Peridineæ* are one-cell Algæ, with curious cellulose walls, made up of close-fitting, angular plates. The wall is traversed by a horizontal groove, in which there is a pore. Through this opening two slender flagella issue; one lies in the groove, and the other is extended freely into the water, and propels the organism by lash-like movements. Some species emit light, and are the chief agents in the luminosity of the water in certain areas of the sea.

Altogether different from the microscopic flora of the plankton is the noted Gulf Weed (*Sargassum bacciferum*), which is found floating in great masses in the tropical and subtropical seas of both hemispheres. It forms ridges 30 to 60 feet wide, and of indefinite length. Columbus mentioned this Alga as having delayed his ships, and the celebrated Humboldt described it. The thallus consists of a branched stem, bearing leaf-like expansions, serrated on their margin. The plant is buoyed up by a number of small, round air-vessels, usually tipped with spine-like projections. It seems that this Alga has for ages formed the "Sargasso Sea," and it is probable that its increase is due entirely to vegetative budding.

Seaweeds have long been used by man as food and in other connections. Irish Moss, or Carragheen (*Chondrus crispus*) and Dulse (*Rhodymema palmata*) are eaten. Ceylon Moss (*Gracilaria lichenoides*), found in Eastern seas, furnishes the well-known Agar-Agar used by bacteriologists as a culture medium, and the Japanese and Chinese in the manufacture of sweetmeats. Some species of Seaweeds are cultivated for industrial purposes in China and Japan. The Kelp industry was at one time an important asset in Britain; it is still of some small value in connection with the manufacture of iodine, but I am led to understand that most of the Kelp used in this direction is now imported.

The structure and development of Green Algæ have received a fair share of attention in the previous chapter, and in what follows in this connection we shall confine ourselves to the Brown and Red Seaweeds.

Within the ranks of the PHÆOPHYCEÆ, or Brown Sea-

weeds, there is much diversity of structure and size. There are small species whose thalli consist of simple threads of cells at the one extreme, and, at the other we find forms with complex thalli, sometimes many yards in length, differentiated into a strong rootlike holdfast, sturdy stem, and a flattened frond. All the forms are multicellular, and it appears that in the more complex species certain cells are told off for particular functions. Thus, some cells act as carbon assimilators, others as conductors of the products of assimilation, and still others serve to strengthen the thallus. Most of the Phæophyceæ are propagated by zoospores; but in the ranks of the Wrack family (Fucaceæ) we find that egg-cells and spermatozoids are formed, and propagation is entirely sexual.

It is within the family Laminariaceæ that we have the giants of the marine forest. Two species are common in the Laminarian zone of the British coasts, *Laminaria digitata* and *L. saccharina*. The former attaches itself to rocks by means of a strong, fibrous holdfast; it has a stout stem as thick as one's thumb, and its leaf is deeply lobed or cut into narrow segments. It grows to a length of above 6 feet. *L. saccharina* has a relatively short stem, and a long, flat, ribbon-like leaf which may reach a length of 12 feet, with a width of about 16 inches. This species is popularly called the "Devil's Apron." *Chorda filum*, variously termed "Sea Laces," "Lucky Minny's Lines," "Dead Men's Ropes," is of the same family. Its long, slender, cord-like frond must be familiar to every coast visitor; he sees specimens on the shore, between tide-marks, and out at sea in several fathoms of water, where it annoys

him frequently enough by becoming tangled about the oars of his boat. This weed is found quite 40 feet in length; it is seldom more than $\frac{1}{4}$ inch in diameter. But these species are mere dwarfs in comparison with some of the great Kelps of the Pacific and the Southern Seas—for instance, *Macrocystis* has an exceedingly slender stem, about $\frac{3}{8}$ inch in diameter, which attains a length of hundreds of feet; this is surmounted by an air-vessel, about 1 inch in diameter, to which a number of ribbon-like leaves are attached. There are nearly one hundred species in the family Laminariaceæ; they do not thrive in the tropics, but are numerous on the coasts of Arctic and temperate seas.

It is remarkable that in a family of Seaweeds in which there is such a decided and even complex development of the vegetative thallus the mode of propagation is of a very simple order. Sexual cells have not been observed among the Laminariaceæ; the plants are known to liberate asexual zoospores which give rise to new plants. But we have yet much to learn concerning the life-cycle of the members of this and other families of Seaweeds.

Let us turn our attention to the genus *Ectocarpus*, of which there are several British species. Here we find some of the simplest Brown Algæ. They are well distributed throughout the coastal regions of the world, and are recorded as being abundant in the North Atlantic. *Ectocarpus siliculosus* forms tufts of slender, much-branched filaments one cell thick; the colour is brownish or olive-green. This repeatedly divided filamentous thallus has a creeping base by which the plant attaches itself to a substratum; it is usually found

attached to larger seaweeds between tide-marks. The whole plant ranges from 6 to 18 inches in length; it is very abundant. The individual cells possess a single nucleus and a number of chloroplasts masked with the brown pigment.

Ectocarpus produces two distinct kinds of reproductive organs, which are called "sporangia" (spore-cases). Both kinds may occur on the same plant, but it is usual for them to develop separately on different individuals; they arise, like branches, from the side of the filament. In Fig. 26 we have a drawing of the simpler kind of sporangia as seen under the microscope. Each sporangium is a single pear-shaped or spherical cell packed with protoplasm, which ultimately divides and gives rise to numerous zoospores. The zoospores of this genus, as in all the Brown Algæ, are furnished with a pair of cilia which emerge from the side, not the apex of the cell. When they are in motion one cilium points in the direction of progress and the other trails behind. In due time the zoospores escape from the sporangium and swim about. They come to rest after a period of activity, and produce new plants.

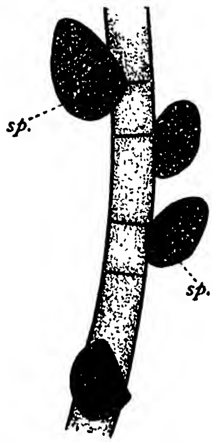


FIG. 26.—SPORANGIA (*sp.*) PRODUCED LATERALLY ON A FILAMENT OF ECTOCARPUS OVATUS. × 300.

The second kind of sporangium (see Fig. 27) is composed of many cells in which motile gametes are developed. Each one of these, like the asexual zoospore, bears two cilia inserted laterally. In *E. siliculosus* it

has been noticed that some of the gametes come to rest prior to the others, and exert some sort of attraction, which causes the still active gametes to swarm around them (Fig. 27, *B*), the result being that one of the active gametes fuses with the resting-cell and produces a zygospore, which produces a new plant. In this way, then, we have sexual reproduction, and we may look upon the gamete which comes to rest first as an egg-cell, the others acting as spermatozoids. It is worthy of note, however, that the gametes can give rise to new plants without conjugating. Asexual propagation preponderates in *Ectocarpus*, but it seems probable that the occasional sexual process results in increased vigour.

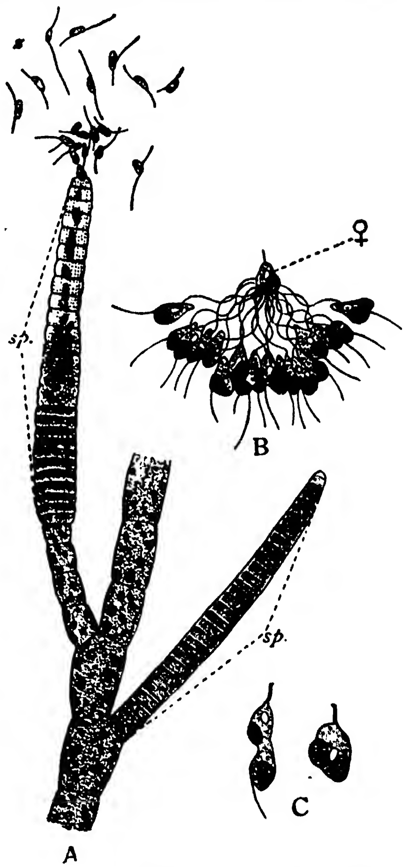


FIG. 27.—ECTOCARPUS SILICULOSUS.
A, Part of branch with two sporangia (*sp.*) which produce gametes (*z*), ×330; *B*, egg-cell (♀) at rest surrounded by a swarm of male-cells; *C*, stages of conjugation. *B* and *C* ×790.

The Fucaceæ are a family of Brown Seaweeds embracing over 300 species, a few of which have already been described; they are most abundant in the

waters of temperate and cold coasts. It is in this family that we have the most advanced type of sexual reproduction among the Brown Algæ; indeed, asexual reproduction is entirely wanting—that is, if we leave out of consideration the fact that detached fragments of a thallus may develop into perfect plants. *Pelvetia canaliculata* belongs to the Fucaceæ. We have already noted a few of its external characters (p. 73), but as we propose to take it as a type of the Wracks, it is necessary that we should consider further points of structure and the nature of its reproductive activity.

In the thallus of *Pelvetia* we have a distinct advance upon the thread-like row of cells joined end-to-end. A cross-section examined under the microscope shows numerous cells, which are arranged in accordance with their peculiar functions. There is an outer ring of cells containing chloroplasts masked with brown pigment; this evidently forms a carbon-assimilating tissue. Inside this ring there is a circle of large cells which are lightly coloured; they probably assimilate carbon, but not nearly so extensively as the cells of the outer tissue. In the centre of the section there are elongated cells which probably serve to conduct food material. At the lower part of the thallus and in the attachment disc the central cells are greatly elongated. They form a tangled network and have strong walls; they serve to strengthen the plant at a point where the action of waves might tear it. The thallus grows in length through the repeated division and subdivisions of a particular cell at the apex. If the thallus is injured at any point, the cells near the wound are not merely active in repairing the damage, but are stimulated to such a

degree that they actually produce a shoot, which may break away and become an independent plant. Thus injury stimulates growth, and within reasonable limits *Pelvetia* is urged to thrive and propagate by "the slings and arrows of outrageous fortune."

It is in the late summer and autumn that we have the best opportunity for studying sexual reproduction in *Pelvetia*. Then we notice that some of the branches become enlarged at their ends, the enlarged parts being studded with wart-like protuberances. The hand-

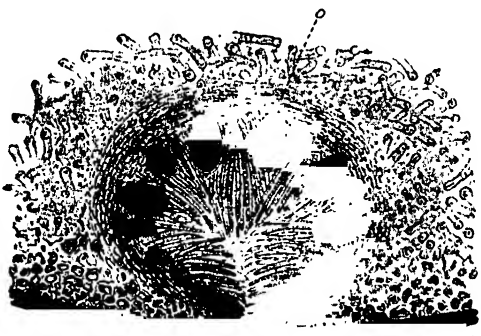


FIG. 28—CONCEPTACLE OF PELVETIA CANALICULATA IN MEDIAN SECTION. × ABOUT 10.

o, One of the egg-cells occurring among the barren hairs (paraphyses).

magnifier helps us to see that at the top of each of these protuberances there is a tiny opening leading into the interior; indeed, the pore opens into a cavity, called the "conceptacle" (see Fig. 28), where are the organs of reproduction. Both male and female organs are found in the same conceptacle. Large, well-nourished egg-cells are found at the base. The male organs (antheridia) are developed on some branched filaments (see Fig. 29), and both kinds of organs occur among numerous barren

hairs (paraphyses) whose tips are directed towards the opening of the conceptacle. The male organ produces sixty-four almost colourless, oval, biciliated spermatozoids. The egg-cell divides into two. The ova and spermatozoids are eventually expelled from the conceptacle, and fertilization ensues outside the parent plant. Only one spermatozoid is permitted to coalesce with an ovum in the fertilizing act. It is apparent that the male elements are produced in excess of the actual requirements in order that there may be no risk of failure in the nuptials; one spermatozoid might miss the mark, and were but one produced the risk would be great. The fertilized egg-cells become surrounded with cell-walls and germinate without entering upon a resting stage, the product of germination being, of course, a new *Pelvetia* plant. From this short account it will be seen that sex is well developed in *Pelvetia*. We have the well-nourished, passive egg-cell and the tiny life-bearing body of an hour, the spermatozoid. The sexes are clearly distinguished, and that they are firmly established is evident from a fact we have not noted—an egg-cell will not give rise to a new plant unless it has been fertilized. This, the reader will have observed, is not always

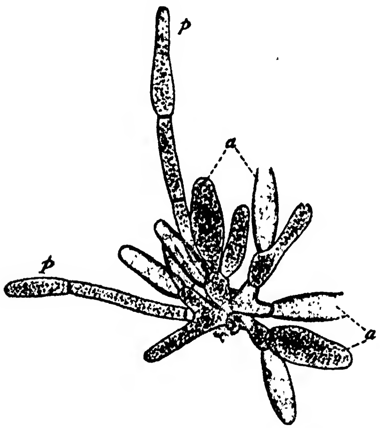


FIG. 29.—PELVETIA. ×260.
a, a, Antheridia (male organs); *p, p,* paraphyses or barren hairs.

the case in Algæ in which sex is not so highly specialized.

In Bladder-Wrack (*Fucus vesiculosus*) the male and female elements are formed in separate conceptacles; they are expelled into the water, where they meet and fertilization takes place. The egg-cell of *Pelvetia* produces two ova, but that of *F. vesiculosus* divides into eight.

The Red Seaweeds, or Rhodophyceæ, are not only marked off from other Algæ by their distinctive colour and their consequent adaptation to deeper water, but they have methods of reproduction peculiarly their own. They form a quite isolated group, displaying no definite affinities; they do not appear to indicate any stage of transition to plants higher than themselves, and we must regard them as a side-issue of evolution, filling their own particular place in the economy of nature. They propagate by asexual spores, and sexually by means of unciliated cells which have no motile power. Some kinds are thickly encrusted with carbonate of lime. Such are the Corallines so frequently found in rock-pools, and which, in some localities, form reefs in the sea. About 1,800 species of Red Seaweeds have been distinguished. There is great diversity of form among them; very few exist unattached to a substratum. In all but the lowest types the protoplasmic bodies of the cells of the thallus are connected by delicate strands of protoplasm.

The asexual spores of the Red Algæ are known as "tetraspores," because they occur four together in a mother-cell; they could not be called "zoospores," as they are not motile. The spores escape from the mother-cell and immediately grow into new plants.

Callithamnion corymbosum (Fig. 30) occurs on rocks and other Algæ. It is pinkish, soft, gelatinous, and glossy when dried. It grows in repeatedly branched

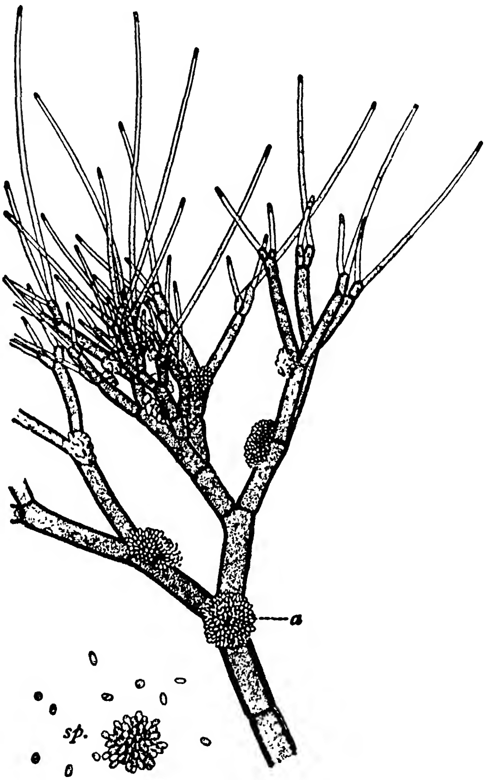


FIG. 30.—CALITHAMNION CORYMBOSUM.

Portion of male plant, with clusters of antheridia (*a*). × about 150. *sp*, A group of antheridia detached, surrounded by free male elements. × about 240.

filaments, the entire thallus ranging from 1 to 3 inches in length. This species is one of the simpler Red Algæ,

in which we can study the reproductive arrangements with some facility. It is common for the tetraspores, the male, and female organs, to grow on separate plants, but all three have been found on one individual. In Fig. 30, *a*, we see magnified clusters of male organs growing on the thallus of a male plant. These clusters consist of short branches, in each one of which the terminal cell becomes specialized into a male element. The contents of this cell draw away from the cell-wall, round off, and ultimately are discharged through an opening in the form of a *spermatium*. It is unciliated and passive, so it drifts in the water quite helplessly, and the fulfilment of its fertilizing mission depends upon the direction of the drift. These male elements are produced in goodly numbers, for not only are the branchlets on which they are produced numerous, but after one terminal cell of a branchlet has ripened and been discharged, the next in succession becomes terminal, and forms a new male organ within the broken membrane of the old one.

A small part of a female plant of *C. corymbosum* bearing a female organ is shown in Fig. 31. This organ is technically designated the "procarpium" (Gr. *pro*, before; *carpos*, fruit). In the species under discussion it is generally composed of five cells, and one of these becomes somewhat enlarged, forming a carpogonium (Gr. *carpos*, fruit; *gonē*, generation). This same cell sends out a thin hair, the trichogyne (Gr. *trichos*, hair; *gyne*, a female), as per Fig. 31, *t*. Such an extension of a female cell as the trichogyne is evidently a well-devised arrangement for catching the male elements as they drift. Seeing that these elements cannot swim

to their destination, it is certainly advantageous to the plant to have a device which will stay them in their drifting. The wall of the trichogyne is gelatinous, consequently a drifting spermatium coming in contact with it adheres (Fig. 31, *s*). The trichogyne is also receptive, and at the point where the spermatium adheres the cell-walls of both the former and the latter are absorbed, and the contents of the male cell pass into the female. Thus fertilization takes place. The first result of this vital act is a remarkable development of the carpogonium. It produces branches and establishes connections with the auxiliary cells, its contents uniting with them. Thus, the effects of the fertilization are passed on to these cells. The auxiliary cells divide, and the ultimate result of fertilization is the formation of a spore-fruit enclosed in a mucilaginous envelope. This fruit consists of a mass of spores, which at the proper time escape from their investment and give rise to new plants. With these facts before us, we must conclude that the sexual arrangements of the Red Seaweeds are of an advanced and complicated character; indeed, not one whit less specialized than those of even the highest land-plants.

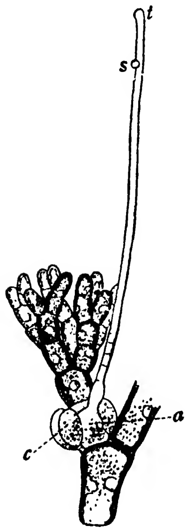


FIG. 31.—PORTION OF BRANCH OF FEMALE PLANT OF CALLITHAMNION CORYMBOSUM BEARING A PROCARPIUM. × 250.

a, Carpogonium; *t*, trichogyne with adherent spermatium (*s*); *c*, another trichogyne cell.

The few facts we have noted about Seaweeds, stated briefly, in cold print, and merely glanced at by an im-

patient reader, will hardly stir his imagination. But the reader who stays to think and read between the lines should not fail to have his pulse quickened by thoughts almost too deep for words. He will form a mental picture of a weed-strewn shore, with the waves breaking upon it. At one moment he will imagine a calm sea lapping the beach gently; at another he will almost hear the roaring breakers. And as he pictures some of the greater Seaweeds moving rhythmically and easily in the ebb and flow of the waters, he will marvel at the wonderful adaptations which enable them to hold their own amidst such turbulence, and even profit by it. Nor, when he contemplates the facts of structure, growth, and reproduction, will he fail to ask himself, "What is at the back of it all? Here," he will say, "are ceaseless activity, teeming life, strange devices, and what might have seemed insuperable difficulties surmounted. How can I account for them? Surely all these things do not happen fortuitously. Do they not rather indicate that Life, instead of being, according to Spencerian speculation, an adjustment of inner and outer relations, is the Adjuster, the Adapter, the silent Surmounter of obstacles, always directive in its activities, and always securing the highest possible manifestation in a given environment?"

In the flora of the sea one could hardly expect a greater advance than we have observed. The development of the Algæ accords well with their environment, and the Seaweeds are successful colonists of their habitat. What more is needed? It is the colonizing of the land that has led to the most striking and diverse specializations of plant forms.

CHAPTER IV

FUNGI AND LICHENS

The Fungi form a most interesting group of plants, and one wonders that the average amateur botanist does not give them more attention. Their number is legion. Over 40,000 species have been distinguished, and new species are being discovered. The botanist who would have an intimate acquaintance with all the known species would need to live to a patriarchal age. The activities of the Fungi are so remarkable, and their growth is often so rapid, their appearance is frequently so sudden and unexpected, that we need not wonder that our unscientific and superstitious forebears associated them with the "wee folk." There is, even to the well-trained mind, something uncanny about them.

The fairies no longer exist, because we do not believe in them. The cold light of science has dispelled the picturesque superstition. Yet I could conduct the reader to folk in the remote Highlands who still mention the "wee folk" with "'bated breath." They would readily credit the story of the two Tavistock maids who benefited by the kindness of the fairies, but of whom one happened to offend the little people. The decree of the offended ones was that the maid was to be lame for seven years, after which she was to be cured by a herb with a name so long and cumbrous that she could

not call it to mind. And, we are assured, the girl became lame, and remained so for the seven years. At the end of that period she happened to be picking a mushroom, when she was startled by the discovery of a strange little fellow underneath the delectable fungus. This fairy—for such he was—struck her leg repeatedly with the wonderful herb until the lameness passed away, and the maid became an excellent dancer.

And there are still some ancient persons, quite medieval in their beliefs, who will point to the fairy-rings in the pastures as evidence of the existence of the little people. If you can get into terms of intimacy with these survivors of the Middle Ages, they will tell you about—

> "The nimble elves
> That do by moonshine green sour ringlets make,
> Whereof the ewe bites not; whose pastime 'tis
> To make these midnight mushrooms."

They are as fully convinced as the old writer who in cold blood wrote of the little people: "They had always fine music among themselves, and danced in a moonshiny night, around, or in a ring, as one may see at this day upon every common in England where mushrooms grow." These fairy-rings are circles, or part circles, of dark grass, which is more luxuriant than that by which it is surrounded. They are sometimes quite ancient, and of very considerable size. They were associated with mushrooms and fairies by the superstitious. The fairies do not now enter into the account, but the mushrooms are admitted. In brief, the rings are due to the operations of the Fairy-ring Champignon (*Marasmius oreades*), an edible fungus. The Rev. M. J.

Berkeley explains thus: "It is believed that these rings originate from a single fungus, whose growth renders the soil immediately beneath unfit for its reproduction. The spawn, however, spreads all around, and in the second year produces a crop whose spawn spreads again, the soil behind forbidding its return in that direction. Thus, the circle is continually increased, and extends indefinitely till some cause intervenes to destroy it. If the spawn did not spread on all sides at first, an arc of a circle only is produced. The manure arising from the dead fungi of the former years makes the grass peculiarly vigorous round, so as to render the circle visible even when there is no external appearance of the fungus, and the contrast is often the stronger from that behind being killed by the old spawn." Alas, for the fairies who made these circles the scene of their nocturnal revels, and, for sheer pastime, made the mushrooms! No longer need we, with palpitating hearts, rush across the common after dark lest we be caught in your toils and carried off to servitude in pixie-land. No longer can we believe that the mushrooms that are to-day, and were not yesterday, rapid as their growth may be, are the clever products of your play. Ruthless science has put you out of the reckoning and given us plain, matter-of-fact accounts, which we, however unwilling, must accept. Peter Pan's good fairy almost expired because she had drunk a poisonous draught. She was restored to active service by the affirmative response to Peter's passionate appeal: "Do you believe in fairies?" But if the fairies are dismissed, the wonder and mystery of life remain. Science may explain the mechanism of a mushroom's growth, and

give us an excellent account of its place in the economy of nature, but it is baffled by the inscrutable forces that are at the back of all phenomena.

The Fungi include Rusts, Smuts, Mildews, Moulds, and Yeasts; but, naturally, the attention of the ordinary observer is caught principally by the Mushroom-like forms, and such conspicuous objects as the Puffballs and Earth-Stars. We shall see later that a Mushroom, a Toadstool, or a Puffball is the fructification of a hidden plant. Many of the smaller Fungi are pests: they are the occasion of diseases in plants and animals, and inflict serious losses upon the agriculturalist. Timber is subject to the ravages of certain kinds. The reader will certainly be familiar with the "dry-rot" Fungus (*Merulius lachrymans*), which destroys the timbers of houses, and can hardly be exterminated once it has got established. The historic potato famines in Ireland were due to the destructive activity of a microscopic Fungus, *Phytophthora infestans*, the Potato-disease, and it may be claimed that this pest played an important part in the Repeal of the Corn Laws. A Fungus causes the Salmon disease; and it is said that the Black Death which devastated England in the reign of Edward III. was due to a Fungus. But while so many Fungi are destructive, we must not conclude that all are baneful. Generally speaking, they perform exceedingly important uses.

Before going into some details of structure and development in the Fungi, it may be well to take note of some easily observed features. First, there is the great range of coloration. This is very evident among the so-called Toad- or Paddock-stools. Green is a rare colour, but it occurs in a few instances. Various shades

of brown are common; there are various yellow tints, and shades of red, from pale pink to crimson. Pure white species are found, while creamy tints are abundant. Blue tints are found, but they are rare. It has been well said that few objects in Nature exhibit more gorgeous tints than the Fungi. In tropical and subtropical regions some species are remarkably luminous. They emit sufficient light, of a phosphorescent nature, to enable one to read at night. The "touchwood" of the schoolboy is a piece of decaying wood from an old tree-stump, which emits a faint light in the dark. The schoolboys of a certain part of Northamptonshire, where I was educated, used to gather it frequently, and take pieces to bed with them so as to profit by the faint luminosity which is due to a fungus which permeates the decaying wood, and is, indeed, the cause of its decay. The odour of some species is exceedingly disagreeable; in others it is not unpleasant. The rapidity of development of the fructifications is worthy of special remark. Well might our ancestors account for the sudden appearances of many species by crediting them to fairies. The Giant Puffball (*Calvatia gigantea*) may grow to the size of one's head in a single night. This means that the cells forming it must multiply at an enormous rate—probably many millions per minute. The Saddle Fungus (*Polyporus squamosus*), which grows on tree-trunks and stumps, has been observed to attain a circumference of over 7 feet, and a weight of 34 pounds, in four weeks. A pasture yielding no signs of Mushrooms on one day may be studded with them in less than twenty-four hours.

Although the tissues of growing Fungi are compara-

tively soft, the fructifications can push their way through soil without being damaged. The photograph on Plate III. shows a group of *Coprinus atramentarius*, which pushed its way through the metal of a garden path. It had to negotiate about 9 inches of solidly compacted ashes, and a top layer of blaes. Fungi have been observed to lift paving-stones from their beds. Sir Joseph Banks was responsible for recording an instance of a wine-cask being lifted to the roof of a cellar by Fungi which had developed from the wine that had leaked out of it.

From quite ancient times Fungi have been used as articles of food. Some species are very poisonous, and none should be eaten unless it is certainly known that they are edible. Many kinds are eaten on the Continent, but in Britain the Mushroom is the only one that forms a popular article of diet, and is cultivated for the market. In a recent publication of the British Board of Agriculture and Fisheries it is stated that poisonous species are comparatively few in number, and there are about fifty kinds that can safely be eaten. Of the edible species, the following are described: Common Mushroom (*Agaricus campestris*), Horse Mushroom (*A. arvensis*), Tufted Mushroom (*A. elvensis*), Bleeding Agaric (*A. hæmorhoidarius*), Shaggy Caps (*Coprinus comatus*), Warty Caps (*Amanita rubescens*), Parasol Mushroom (*Lepiota procera*), Sheathed Agaric (*Amanitopsis vaginata*), Scaly Agaric (*Lepiota rachodes*), Chocolate Agaric (*L. emplastra*), Blewits (*Tricholoma personatum*), Funnel Mushroom (*Clitocybe maxima*), Amethyst Agaric (*Tricholoma nudum*), Horn of Plenty (*Craterellus cornucopioides*), Great Puffball (*Calvatia gigantea*), Edible

Boletus (*Boletus edulis*), and the Common Morel (*Morchella esculenta*). To this list we should certainly add the Yellow Chanterelle (*Cantharellus cibarius*), the Beef-steak Fungus (*Fistulina hepatica*), and the Truffle (*Tuber æstivum*). The Truffle (Fig. 32) has long been considered a table delicacy; it was known to Pliny. There are many species. *T. æstivum* is that usually obtained in Britain. It grows underground in woods, particularly under beech-trees. Dogs are trained to hunt for Truffles, and even pigs, which are very fond of them, are used in some Continental countries for the same purpose.

FIG. 32.—TRUFFLE (TUBER ÆSTIVUM).

The Fly Agaric (*Amanita muscaria*) is highly poisonous. Its popular name is due to the fact that it was used as a fly poison. No fungus could be more brilliant and attractive in appearance. The cap is usually deep scarlet, sprinkled with white patches of the volva; the gills are white. This Agaric favours fir and birch woods. There is another point of interest in relation to this species. M. C. Cooke, in his *Plain and Easy Account of British Fungi*, wrote: "In Siberia it supplies the inhabitants with the means of intoxication similar to that produced by the 'haschisch' and 'majoon' of the East. The fungi are collected during the summer months, and hung up to dry in the open air, or they are left to dry in the ground, and are collected afterwards. When the latter course is pursued, they are said to possess more powerful narcotic properties than when dried artificially. The juice of the whortleberry, in

PLATE III.

FUNGUS (*Coprinus atramentarius*) FORCING ITS WAY THROUGH GARDEN PATH.

which this substance has been steeped, acquires thereby the intoxicating properties of strong wine. The method of using this singular production is to roll it up in the form of a bolus and swallow it whole. A day's intoxication may be procured at the expense of one or two of these fungi, and this intoxication is affirmed to be not only cheap, but remarkably pleasant. The result follows within an hour or two of participation."

If we lay a Fungus-fruit, such as a Mushroom, gills downward, on a piece of paper and remove it after a few hours, we shall find that an almost incalculable number of minute spores have been dropped on to the paper. The colour of the spores—white, black, yellow, or pinkish—is a feature of considerable help in the determination of species. The spores are very light, and it is easy to appreciate the fact that in nature they are readily dispersed, even by the gentlest breeze. But Fungi are by no means completely dependent upon wind for the dispersal of their spores. It is a matter of common observation that many species are eaten by maggots and slugs, and visited by flies; these animals doubtless assist in spore-dispersal. Underground species, like the Truffles, attract animals by their strong scent. The animals eat them, but the spores pass unharmed through their bodies, and are deposited with their excrement. The Phalloidaceæ are a family of Fungi which are most commonly found in tropical countries. We have three British species, and of these the "Stinkhorn" (*Ithyphallus impudicus*) is the best known. The fruit of this evil-smelling plant consists of a thick, fleshy stalk, from 5 to 8 inches high, surmounted at the apex by a cap displaying a raised network of ribs. The cap

becomes covered with a sort of olive-green mucus, which contains the tiny spores, and also provides the "smell." This odour is most objectionable; it can be detected a dozen yards away. But, while it is so disagreeable to the olfactory sense of man, it seems to be particularly attractive to "bluebottle" flies. These insects detect the odour, and make straight for its source. They feed greedily upon the mucus, and, of course, swallow the spores which it contains. The spores pass through the alimentary canal of a fly, quite unharmed by the digestive process, and thus are dispersed over a considerable area. Thus, the "Stinkhorn" has adopted quite a cunning "dodge" in order to secure spore-dispersal.

Fungi of the genus *Cordyceps* are parasitic on insects and have a life-history worthy of special remark. The spores usually infect insects in their larval stage; they may find admittance to the body along with food, or through the spiracles, or breathing-pores, which are arranged along the sides of the body. The spores germinate and give rise to a mass of filaments, which worm their way through the body and feed on its substances. The larva may survive the infection and pass into a chrysalis, or it may be killed before that change takes place. The dead chrysalis or larva undergoes no change in form, but is converted into a tough, cork-like substance. After a time, the fungus projects a somewhat club-shaped fructification as a means of spore-production and dispersal. This spore-bearing organ, in British species, may be from ½ to 1½ inches long. New Zealand furnishes the largest species, some of which produce fruits 6 or more inches

in length. But the fungus may infect perfect insects as well as caterpillars; moths and butterflies, beetles, wasps, bees and spiders are attacked, and the death-rate due to the activity of these Fungi among insects is enormous.

All Fungi are destitute of chlorophyll, hence they are unable to elaborate carbon-compounds from the carbon dioxide of the atmosphere. Such carbonaceous food as they require must be obtained from organic material. Thus Fungi are either saprophytic or parasitic; in the former case they obtain food from the dead bodies, or waste, of animals and plants, while in the latter they prey upon living plants or animals. It is among the parasitic Fungi that we have so many pests, some of which inflict serious financial loss upon man. The saprophytes serve a most important use in that they attack useless organic remains, cause them to decay and form a highly nutritive humus soil in which higher plants may flourish. In this use the Fungi are assisted by the saprophytic Bacteria. Fungi resemble animals in that they consume ready-made organic food, absorb oxygen, and give off carbon dioxide. Such being their habit, they cannot be regarded as primitive plants. It is probably right to assume that they have descended from green Algæ which lost chlorophyll owing to parasitic or saprophytic practices. But while all Fungi are marked by the absence of chlorophyll, we must not conclude that all plants destitute of this pigment are Fungi. There is quite a number of flowering plants, among which Toothwort and Dodder are familiar examples, that

owing to their parasitism have no chlorophyll; such are undoubted descendants from green ancestors, and they serve to illustrate the fact that complete parasitism involves loss of chlorophyll, and the consequent atrophy of all power of elaborating carbon compounds from inorganic materials. However, few Fungi betray any close resemblance to their green ancestors; they are far-removed relations, and have become so modified in structure and development, in adaptation to habit and environment, that their pedigree cannot be traced. But there are some Fungi with most evident Algal affinities, and it will be interesting for us to consider the life-cycle of one of them.

Fungi of the genus *Pythium*, belonging to the group OOMYCETES (Gr. *ōon*, an egg; *mycētes*, fungi) are responsible for much damage to seedlings, on which they are parasitic. They cause the disease known to gardeners as "damping-off"; it occurs very commonly in propagating pits that are allowed to become too damp and warm, and to which light and air are not allowed sufficient access. A plentiful supply of *Pythium Baryanum* may be obtained thus: sow seeds of the common garden Cress (*Lepidium sativum*) in a flower-pot, saturate the soil with water, cover the pot with a piece of glass to exclude overmuch air and ensure a moist atmosphere, and as the seeds germinate, and the seedlings grow, see to it that the water-supply is superabundant. Some of the seedlings will soon display weakness; their stems will bend over, and it may be observed that they show the greatest weakness at the point of curvature; ultimately the diseased stems will fall, lose colour, and become rotten. *Pythium Baryanum*

is the cause of the trouble. Minute spores of this parasitic fungus germinate under favourable conditions, and the fine, colourless, branched filaments which grow from the spores attack the seedlings and live at their expense. These filaments are called *hyphæ*, and the complete thallus consisting of hyphæ arising from a single spore, in any fungus, is termed the *mycelium.* The mycelium, then, is really a vegetative thallus primarily engaged in the business of nutrition.

The reader will remember that in our study of the Alga *Vaucheria* (p. 66) we observed the non-cellular structure of its filaments; microscopic examination of the hyphæ of *Pythium* reveals the fact that septa are either completely absent or extremely rare; so that they resemble *Vaucheria* in this respect. Further resemblance is found in the fact that the hyphæ, although non-cellular, contain protoplasm in which very numerous nuclei occur. In fact, we might almost say that the mycelium of *Pythium* is like the thallus of *Vaucheria* in all respects with the one great exception—it contains no chloroplasts.

The spore of *Pythium* germinates outside the host-plant, and the hyphæ run along the stem. They are, however, not satisfied with mere attachment; they are in quest of food, hence they force a passage into the tissues of their helpless host and absorb the products of its activity. Entrance may be gained through a stoma (p. 21), or a hole is bored through the cuticle. Once admission is secured the hyphæ grow rapidly inside the plant, penetrating into its cells, holding high revel all the while, and ultimately traversing the whole plant, whose death-warrant was signed at the first

moment when the hyphæ had it in their grip. The hyphæ are enabled to penetrate their host, and also convert solid substances into liquids which they can absorb, by means of an enzyme—a digestive ferment. The advancing tip of a hypha secretes the enzyme; this liquefies the cuticle, or cell-wall, and thus opens a passage for the merciless and gluttonous parasite. If the attacked Cress seedlings be kept for a while, under proper conditions, the hyphæ will bind all the seedlings in the pot together in a thick felt, showing that the Fungus is not satisfied with exhausting the seedling first attacked; it will leave its dying host and seek further victims among its healthier neighbours; in fact, it is not satisfied until all the seedlings in the pot are exhausted.

But amid these vegetative saturnalia *Pythium* is not unmindful of the future. Having enjoyed a brief and rapid existence at the expense of its host, with the death of the latter, in the event of further victims being unavailable, the mycelium must needs perish. Hence steps are taken by the parent fungus, before it has exhausted its host, to ensure that it shall at least continue to live in the lives of its children. The individual may be a mere detail and very mortal; but the immortality of the race must, if possible, be secured. In the case of *Pythium* the propagation of the species is both asexual and sexual. In all Fungi, with the exception of the Phycomycetes (Algal Fungi), to which class *Pythium* belongs, sexual reproduction is not generally admitted by botanists. Asexual reproduction is by means of zoospores and *conidia*. The sporangia, in which zoospores are developed, grow at the

ends of short branches of hyphæ that sprout from the host plant into the open air (see Fig. 33). There is a beak at the apex of each sporangium; this beak swells, and becomes a sac for the reception of the whole protoplasmic contents of the sporangium (Fig. 33, *B*). The contents of the sac split up into a number of unwalled cells, and each of these cells becomes an active zoospore furnished with a pair of cilia. These developments can occur only when there is sufficient water to cover the sporangia. The zoospores swim about for a short time, after which they cease to move; in germination they develop hyphæ which, when opportunity favours, will carry on the vicious parasitism of their kind. If water is not sufficient, the sporangia of *P. Baryanum*, although prevented from producing zoospores, are not defeated; they overcome the difficulty by immediately growing into new hyphæ. Indeed, the sporangium, in this event, becomes an asexual spore, termed, in botanical parlance, a "conidium" (Gr. *konis*, dust). Thus *Pythium* in its determination to live and multiply displays much versatility and incidentally gives us an insight into the

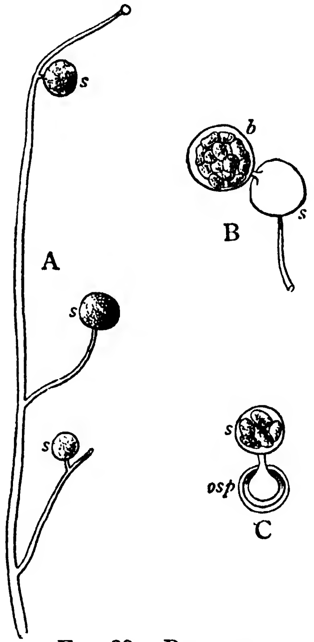


FIG. 33.—PYTHIUM.

A, Branch of the mycelium with three sporangia (*s*), × 125; *B*, sporangium (*s*) discharging contents (*b*), which have become zoospores, × 145; *C*, an oöspore (*osp*) producing an asexual sporangium (*s*), × 300.

method whereby a plant, originally aquatic, may become adapted to land conditions.

But we have not noted the greatest triumph of this ingenious Fungus. It must necessarily come up against such a degree of drought as will make active growth impossible, and, in order to maintain the species through the adverse season, it produces sexual resting-spores. The sexual organs occur on aerial hyphæ and also on hyphæ growing within the host plant. The oögonia (female organs) occur as enlarged spheres at the ends of hyphæ, or at intermediate points. The male organs (antheridia) are club-shaped; they may appear on the same or separate filaments. The fertilizing process is illustrated in Fig. 34. An antheridium reaches out to the nearest oögonium and penetrates it with a fertilizing tube; the contents of the male organs pass through the tube into the oögonium and fertilize the ovum contained therein. Spermatozoids are not formed. The fertilized ovum secretes a stout membrane about itself, develops a store of oil, and enters upon a period of rest, during which it can resist drought and cold, and may be borne a long distance by wind. The resting-spore can germinate only in water, and, in germinating, may behave in three ways: it may produce hyphæ and the usual mycelium forthwith; it may give rise to a hypha which, instead of forming a mycelium, forms a sporangium and zoospores,

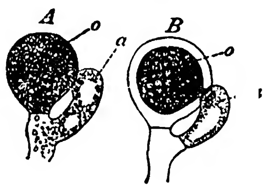


Fig. 34.—The Fertilization of Pythium. × 800.

A, Immature oögonium (*o*), and antheridium (*a*); *B*, the act of fertilization, male elements passing from antheridium (*a*) through the tube to the ovum (*o*).

the complete contents of the hypha passing into the sporangium (Fig. 33, *C*); or it may produce zoospores within itself; these little bodies ultimately escaping, and each one developing into an ordinary *Pythium* plant.

Cystopus candidus, the "White Rust," also one of the Oomycetes, lives parasitically on Shepherd's Purse (*Capsella Bursa-pastoris*) and other cruciferous plants. The hyphæ grow in the intercellular spaces of the host plant, and send out tiny suckers, which penetrate into the cells and absorb their contents. Asexual spores are formed just beneath the epidermis of the host; they cause chalky-white blisters to appear on flowers, leaves and stem, and much distortion of the parts attacked. The blisters burst and liberate the spores, which in the mass appear as a white powder. Under a proper temperature and in the presence of sufficient moisture, the contents of the spores divide into biciliated zoospores, from which new plants arise. Sexual reproduction also occurs, the antheridia and oögonia being formed on parts of the mycelium deeply situated in the host. The fertilized ova are resting-spores, and are set free by the decay of the host.

The group of Fungi known as ZYGOMYCETES (Gr. *zygon*, a yoke; *mykēs*, a fungus) are so named because the sexual process is somewhat analogous to that of the Conjugatæ among the Algæ (p. 34); branches of the mycelium conjugate—that is, are "yoked" together—and their contents fuse, the result being a Zygospore. The mould which commonly grows upon bread, but also appears upon horse-dung and other bases, is usually *Mucor mucedo*. A supply for observa-

tion can readily be obtained by soaking a piece of bread and keeping it under an inverted tumbler. Moulds of different kinds will appear rapidly; among them, on about the fifth day, *Mucor mucedo* will be prominent. It is at first white and woolly; unbranched stalks rise from it, and these stalks terminate in round knobs, white at first, but later turning black. The branched hyphæ of the mycelium are non-cellular, like those of *Pythium;* they penetrate and ramify through the substance of the bread, obtaining nourishment therefrom. The unbranched stalks which rise into the air are sporangiophores—*i.e.*, bearers of sporangia—and the knobs that terminate the stalks are the sporangia, or spore-cases. The contents of the sporangia are divided into numerous oval, smooth-walled spores, which are not ciliated and are evidently adapted to land conditions. These spores germinate under favourable conditions and give rise to new mycelia. The sexually formed zygospores, already referred to, become invested in a thick membrane and can remain dormant for a protracted period without loss of vitality. *Mucor* is certainly better adapted for a terrestrial existence than *Pythium*, and it is more completely fungal in its habits. The Zygomycetes, as a whole, are more terrestrial and far less parasitic than the Oomycetes, and it may be added that the sexual act occurs only when the conditions are not favourable to the formation of sporangia. The more completely fungal the plant, the less does sex appear; in the most advanced Fungi it is not in evidence. About 120 species of Zygomycetes have been distinguished.

Dire plant diseases are caused by the Rust and

Smut Fungi (*Æcidiomycetes*). The various species have their own peculiar host-plants. Thus, we find rusty-red spots of fungal origin on the undersides of Coltsfoot-leaves. *Puccinea suaveolens* covers the under-surfaces of Thistle-leaves with its brownish-red spores. The plants attacked by these Fungi are conspicuous in that they appear sickly and yellow in comparison with their uninfected neighbours. Perhaps the most classical of these parasites is the Rust of Wheat (*Puccinea graminis*), which thrives on cereals during the summer, and in that season scatters orange spores that infect other plants, and thus spread the disease. Later in the year brown, or almost black, spores are produced. These lay on the ground through winter, and constitute a resting-stage. They are termed " teleutospores " (final spores), because they are developed at the end of the season. The teleutospores germinate in the spring. They produce hyphæ, which do not form a true mycelium, but produce special cells, called " sporidia," which are, to all intents and purposes, another kind of spore. Now it is remarkable that the sporidia cannot infect a cereal, or any member of the Grass group. They are destined to fail in their mission if a helpful wind does not drift them on to a particular shrub, the Barberry (*Berberis vulgaris*). The sporidia infect the leaves of this shrub, their mycelia spreading through the tissues and feeding at the expense of their host. Here, again, the passion for reproduction asserts itself. Remarkably pretty little yellow cups are produced from the mycelium, and appear on the under-surface of the attacked leaf (Fig. 35). These cups contain spores, and constitute the æcidium stage of the Fungus, the spores, for

purposes of distinction, being called "æcidiospores." They are of a yellow colour. But the æcidiospores do not infect the Barberry. They can thrive and follow out their purpose only if they are carried by rain or wind to a cereal plant, such as Wheat, or other member of the Grass family. Thus, the teleutospores produced on, say, Wheat give rise to sporidia, which can infect only the Barberry, and the æcidiospores developed on the Barberry are the means whereby the Fungus returns to the Wheat or other member of the same family—surely a most remarkable life-cycle.

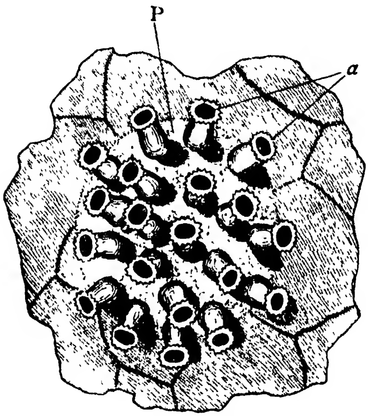


FIG. 35.—PUCCINEA GRAMINIS. × 10.

Portion of lower surface of leaf of Barberry. The swollen part (*P*) bears a group of *Æcidium*-cups (*a*).

We are sorely tempted to linger with the Fungi, and make a study of a goodly number of forms; but the space we can spare to this fascinating group of plants is nearly exhausted, so we must pass rapidly to the consideration of the structure and development of a type representing the BASIDIOMYCETES, an Order which includes the more familiar and conspicuous Fungi, such as Mushrooms, Toadstools, Puffballs, etc. About 10,000 species of Basidiomycetes have been distinguished. The Order has its name from the basidia (*basidium*, a little pedestal), or mother-cells, which bear the spores in the ripe fruits. The Order includes two important Suborders, the

Hymenomycetes and the Gasteromycetes. The Mushroom is a good type of the former, and the Puffball of the latter.

Agaricus campestris, the Common Mushroom, as ordinarily gathered, is merely the fructification of a Fungus, whose vegetative part, the mycelium, lives saprophytically in richly manured soil. The mycelium consists of long, branched, many-celled hyphæ, which ramify through the material in which they subsist. The Mushroom "spawn," sold in the form of bricks, is really a compressed mass of manure and soil containing mycelia. The real Mushroom plant, then, grows in darkness under the surface of the soil. It is probable that from the time of the germination of a spore the mycelium grows and ramifies vegetatively for about seven months before it takes the sudden notion to produce fructifications with almost magic speed.

Fig. 36 illustrates the development of a Mushroom. *A* represents a mycelium composed of branched hyphæ, bearing fructifications in early stages of development. *B* is a young fructification, seen in section, with attached pieces of the mycelium (*m*). *C* and *D* are advancing stages in which the gills (*l*) are developing. In *E*, a later stage, we see some differentiation; we note the thick stalk, more properly called the "stipe" (*st*), the velum (*v*), and the gills, or lamellæ (*l*). *F* shows a nearly ripe specimen, in which we note the pileus, or cap (*h*), born upon the stipe, and the *velum*, or veil (*v*), which in ripe specimens is broken, leaving a ring upon the stipe. The velum protects the under-side of the pileus with its gills during growth; it is shattered later, in order that the gills may be exposed and the spores scattered.

The gills are pink when young, but in maturity they are brown. The whole fructification is formed of hyphæ.

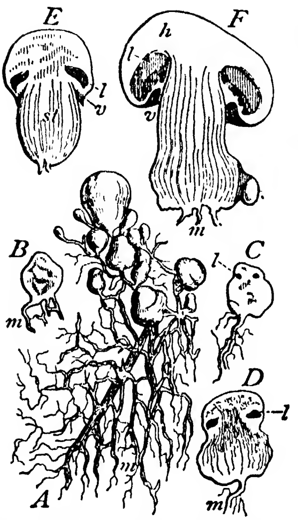


FIG. 36.—LIFE-HISTORY OF A MUSHROOM.

A, Mycelium (*m*) bearing young fructifications. *B*, vertical section of very young fructification; *m*, mycelium. *C*, fructification further advanced, the gills (*l*) appearing. *D*, fructification still more advanced; *l*, gills; *m*, mycelium. *E*, older fructification; *l*, gills; *st*, stipe; *v*, velum. *F*, almost fully developed; *h*, pileus; *l*, gills; *v*, velum; *m*, mycelium.

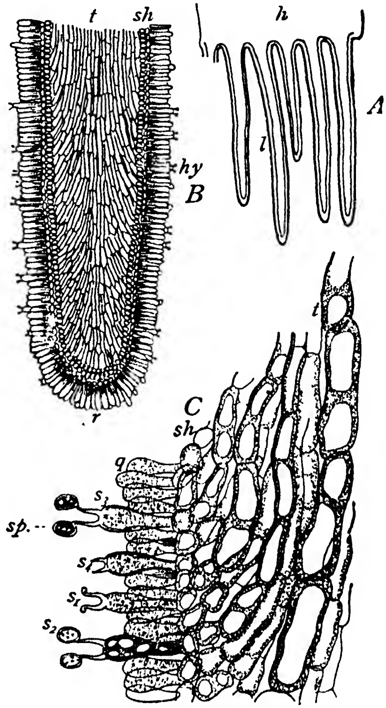


FIG. 37.—LAMELLÆ, OR GILLS, OF MUSHROOM.

A, Small portion of tangential section of pileus (*h*), with gills (*l*) magnified. *B*, section of single gill, × 80; trama (*t*); *hy*, hymenium; *sh*, sub-hymenial layer; *r*, lower edge. *C*, Enlarged part of *B*, × 370; *q*, paraphyses; s_1-s_4, basidia in different stages of growth; *sp*, basidiospores; *sh*, sub-hymenial layer; *t*, cells of trama.

We now turn to Fig. 37, from which we shall learn some interesting facts in regard to the gills. *A* repre-

sents a slightly magnified portion of a tangential section of the pileus (*h*), showing the gills (*l*), which are evidently extensions of the hyphæ of the pileus modified into delicate plates. *B* is a section of a single gill, magnified about 80 diameters, to enable us to note the structure. We observe the *trama* (*t*) formed from hyphæ emergent from the pileus; *sh* is a layer of short, closely packed cells, called the "sub-hymenial layer"; while *hy* is the hymenium, composed of cells which are at right angles to the surfaces of the gill. The hymenium (Gr. *humen*, a membrane) is the spore-bearing part of the gill. It is formed of well-nourished club-shaped cells, some of which do not produce spores, and are more slender than the others; they are the paraphyses (Gr. *para*, beside; *phusis*, growth). The remaining cells of the hymenium are stouter than the sterile cells; they are the basidia, from which the Order Basidiomycetes gets its name, and they are specialized for spore production. In *C* of our figure we have a part of a gill section magnified 370 diameters; *t* is a portion of the trama; *sh*, the sub-hymenial layer, and the cells standing out at right angles are cells of the hymenium. The letter *q* stands for the paraphyses; $s_1 - s_4$ show the basidia in various stages of growth. The basidia produce little apical outgrowths, from two to four to each basidium, and each outgrowth produces a spore (*sp*). Millions of spores are developed in a single fruit.

The spores produced from a basidium are termed "basidiospores." They are the only kind of spores occurring in the Basidiomycetes, in which Order sexual organs are entirely wanting. The Suborder Hymenomycetes has the hymenium naked, and in the mature

fruit the basidia, with their spores, are exposed to the air. In the Gasteromycetes the hymenium is protected by a membrane until the spores are mature. If we make a section of a young Puffball, we may note a central cellular, soft, white mass, surrounded by a thin skin. At a later stage small chambers appear in the central mass, and in the walls of these chambers spore-bearing basidia are developed; later still, the tissues of the mass dissolve, and the spores are found in an evil-smelling, watery mess. Ultimately the moisture evaporates, the outer skin bursts, and the dry spores are dispersed by the wind or other agency.

LICHENS.

The Lichens, or Crottles, as they are called in Scotland, exhibit just about as cunning an arrangement as can be discovered among the many amazing strategies of the plant world. For a long time botanists hardly knew what to make of them, and where to place them; but we now know that a Lichen is not, strictly speaking, an individual plant: it is, practically, a business partnership of two plants, one an Alga and the other a Fungus. Now, an Alga requires abundance of moisture, otherwise it cannot develop; and a Fungus does its vegetative work in the dark, and is extremely delicate; it shrinks from cold and drought; but a Lichen, which is a combination of two delicate plants, is about as hardy a structure as we can find in the whole realm of nature. It can endure the greatest extremes of temperature; species growing on rocks at great altitudes pass unharmed through weeks of keen frost, and are unscathed

by repeated exposures to burning sunshine. A protracted period of drought does a Lichen no more disservice than long submergence in water. And Lichens revel in light and air to a degree that would be the death of the mycelium of a Fungus.

The Alga-Fungus partnership of a Lichen is in all respects remarkable. The Alga is involved in the mycelium of the Fungus; it is protected by it, and it enables the delicate organism to exist in situations where it certainly could not live by itself. The Alga owes more than protection to its Fungus-partner, for the latter supplies it with water and salts in solution. In return for these services, the Alga manufactures organic food by means of its chlorophyll, using carbon dioxide from the air, and grants the Fungus a supply sufficient for its needs. Thus, the Fungus-partner, which can live only on ready-prepared organic matter, is benefited by its relations with the Alga-partner. One can hardly say that the Fungus lives parasitically on the Alga, although it feeds at its expense. It is a case of service-for-service, and may be classed as symbiosis—*i.e.*, mutual living. But in the Lichen partnership the Fungus seems to be predominant. Generally speaking, it controls the Alga and takes the lead; it also determines the form of the Lichen.

Some very interesting experiments have been carried out in recent years in relation to Lichens. The partners have been separated, and it has been demonstrated that the Alga-partner, freed from the embrace of its Fungal symbiont, can live and thrive independently, if provided with suitable environment. The spores of the Fungus-partner have also been reared in specially pre-

pared nutrient solutions in the laboratory, so it would seem as if the Fungus can exist independently of the Alga; but, it must be noted, we have evidence of only one species living apart from its Alga in a state of nature. Experimenters have been able to synthetize Lichens by rearing spores of Lichen-fungi on free Algæ. The Algæ which enter into the Lichen partnership are relatively few in species. They are representatives of the Blue-green Algæ, and some members of the Green Algæ, the Chlorophyceæ. On the other hand, the Fungi entering into the structure of Lichens are very numerous. As the Algal-partners are few in relation to the Fungal-partners, it is patent that the same species of Alga may join with several species of Fungi, otherwise there would not be sufficient kinds of Algæ to go round.

Seeing that the Fungus element in a Lichen is predominant, and that the Algal-partners can exist independently, and, moreover, be identified as species commonly living by themselves, it is now deemed proper to classify Lichens in accordance with the nature of their Fungal constituents. This position seems fully justified when we realize that it is always the Fungus-partner that produces the fructifications. The Algæ multiply by division. The majority of the Fungi entering into Lichen-partnership belong to the Ascomycetes, an Order of Fungi in which the spores are developed inside tubular sporangia, called *asci* (Gr. *askos*, a leather bottle). Never more than eight spores occur in a single ascus. Further, most Lichen-Fungi belong to a Sub-order of the Ascomycetes, yclept the Discomycetes—distinguished by the fact that the ascus-bearing surface

is placed on a flat or saucer-shaped arrangement, and is always exposed at maturity. But the structure of Lichens will be better understood if we study a particular example with the assistance of some drawings.

The Lichen *Physcia parietina* (Fig. 38) is abundant on rocks, palings, old roofs and walls in the neighbourhood of the sea. It forms flat, reddish-yellow rosettes, which evidently grow adpressed to their substrata in order to avoid being torn by the wind. Being

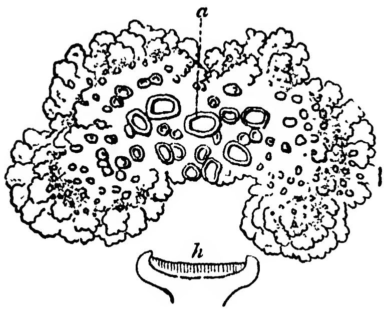


FIG. 38.—THE LICHEN PHYSCIA PARIETINA THALLUS. AS SEEN FROM ABOVE, NATURAL SIZE.

a, Apothecia; *h*, vertical section of apothecium, showing hymenium. × about 5.

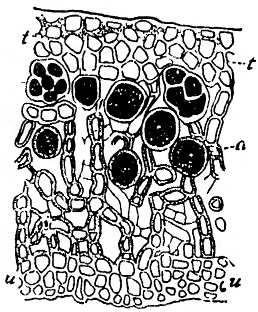


FIG. 39.—VERTICAL SECTION OF THALLUS OF PHYSCIA PARIETINA. × 500.

t and *u*, Upper and lower cortical layers; *a*, captive algæ.

very conspicuous, it is easily seen by insects, and they may be observed crawling over the surface and becoming dusted with the spores: doubtless insects are instrumental in spore-dispersal. The growth of this and allied species is far from rapid. It is calculated at ½ inch per annum, so a specimen 6 inches in diameter will probably be about twelve years old.

The structure of the thallus of *Physcia* is shown in the transverse section, which in Fig. 39 is magnified

500 diameters. The upper and lower layers, *t* and *u*, consist of dense tissue elaborated from the hyphæ of the Fungus-partner. The captive Algæ, some of which are shown increasing by division, are indicated by *a*. It will be observed that they are situated in what is known as the "medullary zone," where the hyphæ are loosely arranged and there are plentiful air-spaces. They are, also, in the upper part of this zone, and, therefore, nearer the upper surface of the thallus than the lower. Thus, the Fungus which holds the Algæ captive takes care that they shall benefit by light, and have a sufficiency of air; otherwise they would not be able to form carbonaceous food, and so supply their captors with nourishment. In *Physcia parietina* the Algal-partners are of the one-cell species, *Cystococcus humicola*, and closely related to *Pleurococcus*, described on p. 55.

The fruits of this Lichen are indicated by *a* in Fig. 38. They, in common with the fruits of the Discomycetes generally, are distinguished by the term "apothecia" (Gr. *apothēkē*, a storehouse). In the same figure, *h* represents a somewhat magnified apothecium, seen in section, with the exposed hymenial surface. The fruits are easily seen by the naked eye; they are deeper in colour than the thallus as a whole, and appear as flat discs surrounded with rims at their edges. A highly magnified vertical section of an apothecium is shown in Fig. 40. Above we note the paraphyses, or sterile hairs, *p*, the asci, *a*, two of which contain eight spores, *sp*, each. The whole surface of the disc within the rim is covered by the *thecium*, as the layer containing the asci and paraphyses is called. The asci, of course, are very

numerous, and the total spore production is great. In the same section we observe two layers of Algal cells, *A*, *A*, the medullary zone, *m*, and the upper and lower cortical layers of densely packed hyphæ, *c*, *c*, the upper cortical layer in the fruit forming the *hypothecium*.

The spores, when fully ripe and other conditions are favourable, are expelled from the asci with much force, and become dispersed; they are pure Fungus spores, and, therefore, cannot form a Lichen unless they meet cells of the Alga *Cystococcus humicola*. Once such a meeting is effected, the partnership becomes established, and the Fungus-partner, now furnished with food-supplies, takes the lead in the formation of a new *Physcia parietina* thallus.

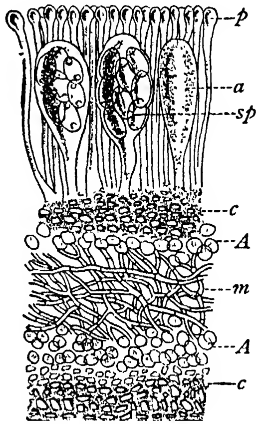


FIG. 40.—VERTICAL SECTION OF AN APOTHECIUM OF PHYSCIA PARIETINA, × 250.

a, Asci, two of them containing eight ascospores (*sp.*) each; *c*, (below) lower cortical layer; *c*, (above) hypothecium; *A*, *A*, strata of algal captives; *m*, medullary layer; *p*, paraphyses.

In some Lichens tiny heaps, patches, or balls of a powdery appearance are formed; they consist of a few Algal cells and fragments of hyphæ, the latter enclosing the former. The term *soredia* (Gr. *sōros*, a heap) is applied to these patches. They are formed below the surface of the thallus, but are finally pushed above it, and become dispersed by insects, wind, and rain; they serve to reproduce the Lichen vegetatively, and must be very useful to the species, because, in their case, hunting for partners is

not necessitated. The formation of soredia has not been observed in *Physcia parietina*.

There is some diversity of form among the Lichens. We find species with flattened stems and erect branchings growing on rocks on the seashore and on old trees. The familiar " Old Man's Beard " Lichens grow on the bark of trees in old woods; they are of two genera, *Usnea* and *Alectoria* ; the former occur as upright tufts, and the latter hang from branches, growing to a length of nearly a foot. The Cluster Cup Lichens (*Cladonias*) bear cup or trumpet-like parts, about an inch in height, on which soredia and spores appear. *Physcia* is one of many leaflike or foliaceous species. The crustaceous, or encrusting, kinds form scales, crusts, or the appearance of a stain, on rocks, bark, etc.; they stick exceedingly tenaciously to their substrata. There are also gelatinous forms, such as *Collema pulposum*, in which the Algal-partners are evenly distributed throughout the thallus, and thus are not confined to any particular zone, as is the case in the type we have just studied.

Lichens, from a human view-point, are not utterly useless. The Reindeer-moss Lichen, to which the word " moss " ought never to have been applied, serves as food for reindeer. Iceland Moss (*Cetraria islandica*) makes excellent jellies. Various species yield dyes of excellent quality, but they are falling into disuse owing to being superseded by aniline dyes. Yet in remote places, such as the Highlands of Scotland, Lichens are still occasionally used in preparing dyes. The colouring material known as Archil, or Orchil, is made by treating powdered Lichens with ammoniacal liquor. Cudbear, used of old as a purple dye for woollen yarn, was prepared

by treating the Lichen *Lecanora tartarea*, which grows on rocks, with stale urine, water, and chalk. Litmus, which is exceedingly valuable to chemists as a test for acids or alkalies, is prepared from certain Lichens. An acid turns blue litmus red; an alkali, such as ammonia, will change the red back to blue.

CHAPTER V

THE ARCHEGONIATES: I. BRYOPHYTES—LIVERWORTS AND MOSSES

ALL the plants we have studied up to the present are classed as Thallophytes, a miscellaneous assortment of forms which may be roughly characterized as showing no distinction between stem and leaves; this definition, however, does not hold good in every case. As it is not our purpose in this book to discuss nice distinctions, we deem it sufficient to state that all plants lower in organization than the Liverworts and Mosses are considered to be Thallophytes.

The Archegoniates (Gr. *archē*, beginning; *gonē*, generation, seed) include the Liverworts, Mosses, Ferns, Horsetails, and Club-mosses, all of which display a marked similarity in the origin and structure of the female reproductive organ—the archegonium. All plants in this division show a marked alternation of generations. The sexual generation is the *gametophyte* (Gr. *gamos*, marriage; *phyton*, plant); it bears the *archegonia* (female organs) and the *antheridia* (male organs). Each archegonium contains an egg-cell, which, after fertilization by a spermatozoid, liberated from an antheridium, becomes an embryo. The asexual generation develops from the embryo; it is termed the *sporophyte* (Gr. *sporos*, seed; and *phyton*); it is found attached to and dependent upon

the gametophyte throughout its existence, or, at least, for part of its life. The sporophyte, when ripe, produces spores from which gametophytes appear. This alternation of generations will appear more clearly to the reader when we come to study concrete examples; for the present the following manner of statement will be of some assistance:

Sexual Generation.	*Asexual Generation.*
Gametophyte	Embryo
Antheridia Archegonia	Sporophyte
Embryo	Spore (from which gametophyte arises)

In the Bryophytes (Gr. *bryon*, moss), which embrace the Liverworts and Mosses, the gametophyte may be thalloid or leafy; it lives independently; it has no true roots: the sporophyte bears no leaves, and remains attached to the gametophyte throughout its existence.

The Liverworts, or Hepaticæ, are unfortunately named. An Italian botanist, Micheli, early in the eighteenth century gave the name to a species on account of its fancied likeness to a liver, and it has stuck to the group in spite of the fact that the majority of the species have not the slightest resemblance to that organ. About 4,000 species are known to science, yet the group as a whole, although so numerous and in every way interesting, has not received the general attention that it so richly deserves; many amateur botanists hardly recognize its existence. This ignorance of the Hepaticæ is probably due, to a large extent, to the fact that most species are very inconspicuous and require searching for; besides, the searcher has to have a good idea of

what he is looking for, otherwise his search is not likely to be successful. But there are species, such as *Marchantia* and *Pellia*, which grow in large and conspicuous patches in damp places, and can hardly be overlooked. Liverworts do not form so well-defined a class as the Mosses, and it is difficult to find one species which may be regarded as typical; they occur in great variety of form, and the class as a whole is so loose that grouping into Orders is difficult. It may be said, however, that in regard to outward appearance there are two groups: (1) The Thallose Liverworts, in which the gametophyte displays no distinction of stem and leaf; and (2) the Foliose Liverworts, in which such a distinction is apparent. The uninitiated observer might mistake the foliose species for Mosses, but a little attention to detail will yield knowledge of several points of distinction. The leaves of the Foliose Liverworts display a somewhat filmy appearance, and the whole plant, as a general rule, has a "flat" mode of growth. With few exceptions, Liverworts are dorsi-ventral—that is, they have upper and lower surfaces, the former exposed to the light, the latter facing the ground. The tissues are very simple, and in many of the foliose kinds the green coloration is extremely delicate. As to habitats, Liverworts are moisture-loving plants and fond of a clean atmosphere; this may also be said of Mosses, but not to the same extent. Districts in which there is a heavy rainfall and smoke-contamination is absent are favoured by Liverworts; they may be found growing in woods, on wet banks, dripping rocks and walls, on the banks of shaded streams, in the neighbourhood of waterfalls and cascades, where they are spray-splashed and often submerged.

Some species are found associated with Mosses, growing amongst their stems and leaves, and appearing delicate, pale, and even threadlike by contrast with their sturdier associates. Other species grow flattened and branching on the trunks of trees, still others on almost bare soil, and some are aquatic. The Liverworts are well described as amphibious; they are mostly terrestrial, but as their male elements, the spermatozoids, are biciliate, and must needs swim to the archegonia in order to fertilize the egg-cells, the plants are aquatic so far as dependence upon a sufficiency of water for this purpose is concerned.

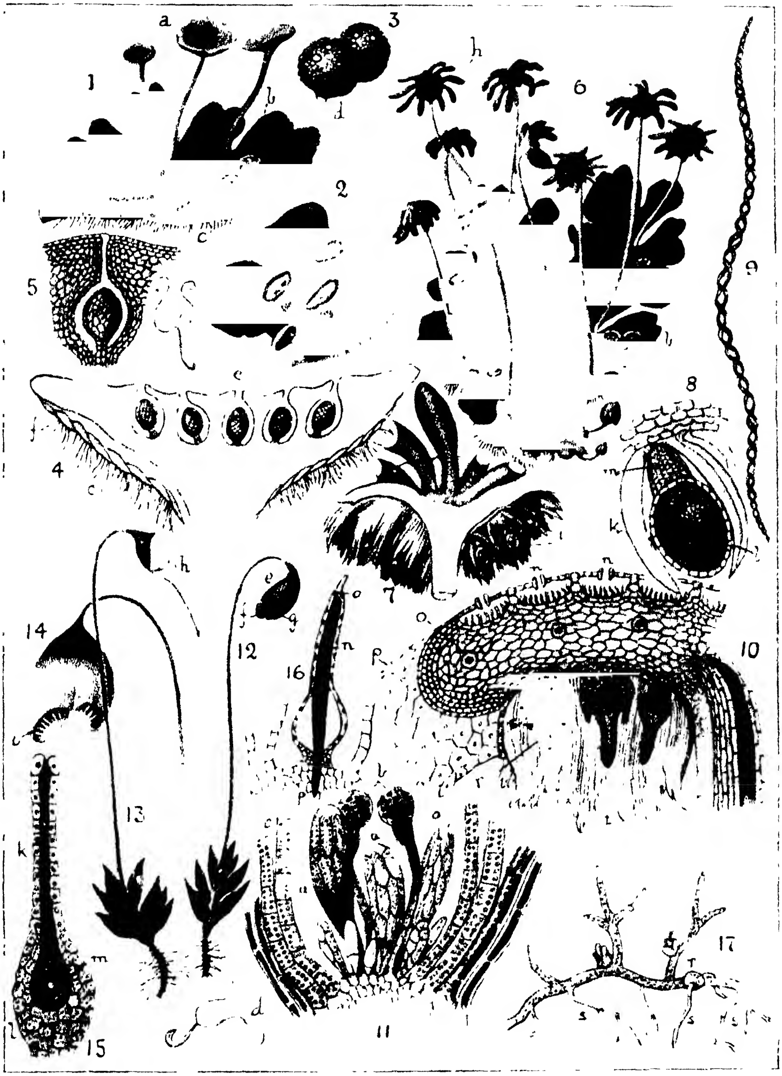
Strasburger, in his *Textbook of Botany*, divides the Hepaticæ into four Orders: The *Ricciaceæ*, the *Marchantiaceæ*, *Anthocerotaceæ*, and the *Jungermanniaceæ*. Kerner adopts the same divisions. Professor D. H. Campbell, in his *Structure and Development of Mosses and Ferns*, divides the Liverworts into two Orders, the *Marchantiales* and *Jungermanniales*, and questions whether the *Anthocerotes* should not properly be taken out of the Liverworts entirely, and be given a place intermediate between them and the Ferns, etc. In the present sketch it will be sufficient for us to follow the divisions of Strasburger.

The Ricciaceæ.—There are 110 species in this Order, no less than 107 belonging to the genus *Riccia*. The majority of these are small. They are of the thalloid type, and occur in the form of small rosettes on clay soil. *Riccia natans* is aquatic, and floats on the surface of water like Duckweed; *R. fluitans* grows submerged in water; but both species can adapt themselves to damp soil, on which they, like most *Riccias*, form flat rosettes

which to the casual observer look like flimsy flakes of green tissue. *R. fluitans*, with other submerged species, is sterile so long as covered by water; it fruits only when exposed to the air. The thallus in this Order may be lobed or branched; it is furnished with delicate rhizoids, proceeding from the under-surface, by which it is attached to its substratum. The rhizoids are not roots. The structure is of the simplest type found among the Liverworts. The male and female organs occur in sunk chambers on the upper side of the thallus. The fertilized egg-cell becomes a stalkless spore capsule containing spores.

The Marchantiaceæ.—Somewhat over 160 species are known to science. The members of this Order are in every way an advance upon the Ricciaceæ, and the structure is frequently distinctly complicated. It is proposed to devote a little space to a study of a very common species, in order that the reader may the better grasp the life-story of a fairly representative Liverwort.

Marchantia polymorpha grows freely on damp soil and in damp places generally; it may be found on old walls, on the walls of hot-houses, and even in plant-pots; its life-history is fully illustrated on Plate IV. The thallus—*i.e.*, the gametophyte—is flattened and prostrate; it is deeply lobed, and produces two-lobed branches; the margin is wavy. There is an inconspicuous midrib, and rhizoids, proceeding from the under-surface, attach the thallus to its substratum, some of them serving as water-conductors. There are scales, consisting of a single layer of cells on the under-surface; while the upper surface is marked out in diamond-shaped areas, in each of which there is a central pore, leading



LIVERWORT (*Marchantia polymorpha*) (Figs. 1 to 10)
MOSS (*Funaria hygrometrica*). (Figs. 11 to 17.)

For details see text.

into an air-chamber; to the naked eye the pores look like mere dots. The air-chambers are relatively large; they are, as it were, roofed, and air finds access only through the pores or stomata. Filaments of nearly globular cells rise from the floor of each chamber; these cells contain chlorophyll, and are the principal means of carbon-assimilation. The whole upper surface is of a dull, dark green colour.

Plate IV., Figs. 1, *b*, and 2, show what are called "gemmæ cups," which are usually found growing over the midribs; the cups have toothed edges, and each contains a number of flattened, stalked gemmæ (L. *gemma*, a bud); a single gemma, enlarged, is shown in Fig. 3 of the same plate. When the gemmæ are mature, they become detached and scattered, and if they drift to a suitable site, they grow into new plants; they are an asexual means of propagation.

The reproductive organs occur on highly specialized branches of the thallus, and the sexes are represented on different plants; they do not appear together on the same plant. These specialized branches are erect, narrowed into a stalk below, and expanded into an umbrella-like, lobed disc at the apex. A branch bearing male organs, antheridia, is called an "antheridiophore" (Plate IV., Fig. 1, *a*), and the antheridia are found on the upper surface of the lobes of the disc, in flask-shaped depressions (see same plate, longitudinal section of antheridiophore, Fig. 4, *e*; and Fig. 5, single antheridium, enlarged). The antheridia produce biciliated male elements, the spermatozoids (Fig. 5, *g*).

The specialized branches borne by the female plants are called "archegoniophores," because they bear

archegonia. A female plant with archegoniophores, *h*, is shown in Plate IV., Fig. 6; it will be noted that the disc of the archegoniophore is split into nine rays, or arms. The female organs, archegonia, are flask-shaped bodies, arranged in groups which are suspended in an inverted position between the arms of the disc, and surrounded by toothed sheaths; a sheath is technically known as a "perichætium." In the same plate, Fig. 10, we see a section of an archegoniophore, showing, *n*, pores leading to air-chambers; *o*, mucilage cells; *p*, ray; *r*, archegonium with egg-cell in centre; and *t*, the perichætium. The mucilage secreted by the mucilage cells diffuses some of its substance into the film of water, which must be present if the sexual act is to take place; water supplied by rain or dew is sufficient. The substance diffused by the mucilage attracts the spermatozoids from a male plant; they swim to the archegonium, enter at the opening of the neck, and traverse the canal towards the egg-cell. Only one spermatozoid is permitted to fuse with the egg-cell in the process of fertilization.

So far, we have outlined the story of the gametophyte. With the fertilized egg-cell, which immediately becomes an embryo, we enter upon an account of the sporophyte, or asexual generation, consisting in this case, when mature, of an oval sporogonium, or capsule, with a stalked foot. Spores are developed in the capsule, and among them are found curious elongated cells, called "elaters." The elaters are hygroscopic; if we breathe upon them, and in the meantime examine them under a low power of the microscope, we shall see them make some curious movements, occasioned by the moisture

of the breath. Similar movements take place in Nature, while the elaters are amongst the spores; they are, doubtless, a device for spore-dispersal. Both elaters and spores are discharged together from the ruptured capsules. The structure of the sporogonium is illustrated in Plate IV., Fig. 8; and in Fig. 9 we have a drawing of an extended elater as seen under the microscope. The spores, on germination, give rise to new gametophytes.

In giving the outline of the structure and development of *Merchantia polymorpha*, we have stated only the salient features, and have omitted several minor details; sufficient, however, has been said to indicate that this plant, apparently so humble, and so frequently ignored, has really quite a complicated structure, and is most ingeniously adapted to the conditions in which it thrives. In the floating *Riccia natans* we can imagine an Alga with flattened thallus adapted to floating conditions, and with modified reproductive organs. The same plant stranded on mud has power to adapt itself to the change, and then displays decidedly amphibian characters. In *Marchantia* we have a more decided terrestrial plant, but one that is aquatic in relation to its fertilization. The great probability is that the Liverworts have descended from Algal ancestors, and that they represent a series of stages whereby plant-life, originally aquatic, has advanced in the conquest of the land. The gemmæ of the Liverworts may be regarded as highly modified zoospores, and the male and female elements, particularly the ciliated spermatozoids, argue strongly in favour of an aquatic ancestry.

Anthocerotaceæ.—The species distinguished number 103. The gametophyte is a simple, irregular, disc-

shaped thallus, each cell being occupied by a single large chloroplast containing a pyrenoid (p. 32); in this respect the cells of the Order differ from those of all other Bryophytes. The archegonia are sunk in the upper surface of the thallus; the antheridia rise from cells that divide beneath the epidermis, and they remain in cavities below the surface until they are mature. After the archegonia have received the spermatozoids and the egg-cells are fertilized, the adjoining tissue overarches them. The growing sporogonium eventually ruptures the covering tissue, which then forms a sheath round the foot of the capsule. The sporogonium is a long podlike capsule with a swollen foot. In liberating the spores, the capsule splits longitudinally, exposing a long central strand of sterile tissue—the columella. Elaters occur among the spores. It is remarkable that stomata are found in the walls of the sporogonium, and its cells contain chlorophyll; this indicates capacity for carbon assimilation and an attempt towards independence of the sporophyte, such as is not shown in other Liverworts. It is probably because of this capacity for self-help that in all the Anthocerotes the sporophyte does not wither so soon as its first spores are ripe; but it continues to grow for a time, and produces a succession of spores. In this Order we have a further illustration of the strange relations of plants highly divergent in character; colonies of the Blue-Green Alga *Nostoc* are always found in intercellular cavities of the thallus.

Jungermanniaceæ.—Named after Jungermann, a German botanist of the seventeenth century. This is by far the largest Order of the Liverworts; it includes over 3,500 species, some of which are thalloid, but most are

leafy, creeping forms, the leaves being composed of a single layer of cells, and the cells of both leaves and stems are of a similar kind. The sporogonium is characteristic; it consists of a long stalk surmounted by a spherical capsule, and the latter, in order to discharge the spores, always splits into four valves, which, together with the elaters, are hygroscopic, and by their movements assist in scattering the spores. The germinating spore may produce a young gametophyte directly; but in some thalloid forms, and in all the foliose species, the first product from the spore is a *protonema* (Gr. *prōtos*, first; *nēma*, thread)—a stage of development strongly marked in the Mosses, which will shortly receive our attention. The species of the Order are usually small in size; they grow on moist earth, on the bark of trees, and on stones; in the tropics they occur on the living leaves of other plants.

Pellia epiphylla is an abundant species of the Order, and a good example of the thalloid form. It grows in many situations—on walls, by the side of springs, on the banks of streams, in damp woods, and in other places where moisture abounds. The thallus is lobed and branched, and the plants occur in large patches. Fig. 41 gives a general view of a single plant, and Fig. 42 shows a part of a thallus with antheridia and rhizoids, or root-hairs. *Metzgeria* is also thalloid, the thallus being ribbon-like and branched. *M. furcata*, the Forked Liverwort, is common in Britain, growing on rocks, but more abundantly on tree-trunks, where it works its way in and out of crevices, clinging firmly to the bark; its forked ribbons are not more than a millimetre in breadth; they display a distinct midrib.

Riella helicophylla is aquatic; it is thus described by Montagne: "Figure to yourself an axis consisting of a nerve round which is wound in a most regular and elegant spiral a membranous wing of the width of 5 millimetres, of the most beautiful green, and of extreme delicacy, in such manner as to form with it a kind of gimlet or helix in inverted cones." Species of *Riella* have been found in regions adjacent to the Mediterranean, the Canary Islands, and the United States.

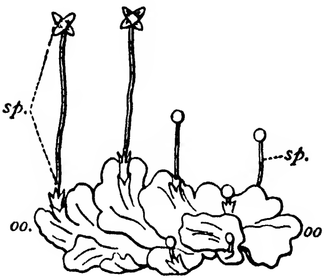


FIG. 41.—GENERAL VIEW OF A SINGLE PLANT OF THE LIVERWORT (PELLIA EPIPHYLLA).

oo, Lobed thallus, the gametophyte generation; *sp*, the fructifications, the sporophyte generation. About half natural size.

FIG. 42. — PELLIA EPIPHYLLA, PORTION OF THALLUS SEEN FROM ABOVE.

an, Antheridia; *r.h.*, root-hairs.

Lophocolea bidentata, the Two-Toothed Liverwort, is also very common in Britain in shady situations; I have found it growing on wet rocks, on earth, and among Mosses. It is a good example of the more delicate foliose Hepatics; its pale green leaves each bear two strongly outlined teeth at the apical margin.

The Tubercled Liverwort, *Frullania dilatata*, another of the leafy forms, grows on the bark of trees, and may

easily be overlooked. Its colour is usually brownish, with a violet cast, and it blends well with the colour of the bark. It is small, and might be mistaken at first sight for a tiny patch of rust. It has three rows of leaves. Two are seen from above, the leaves being rounded and overlapping; the third row is ventral, and the leaves are specialized into toothed scales. The upper leaves are two-lobed, one lobe being much smaller than the other. This smaller lobe is folded back on the under side of its principal, and forms a sort of pitcher. A branch, examined under the microscope, on its under side, gives the appearance of having a double row of inverted pitchers. It is probable that these vessels are for water-storage; but whether this is so or not, they hold water, which is often sufficient to maintain a Rotifer, an animal of microscopic proportions. It is curious to find Rotifers in such a home. They doubtless find excellent shelter and sufficient food for their small requirements; but there is no evidence to show that they confer any benefit upon the plant, or that they get anything from it more than shelter.

Musci: The True Mosses.

In the Mosses, which form the second Class of the Bryophytes, we have subjects more familiar to the average person, and if he does not have an intimate knowledge of their anatomy and life-history, he at any rate knows a Moss when he sees it, and may hold it in some sentimental regard. He may even call to mind Ruskin's panegyric on the Mosses: "Meek creatures! the first mercy of the earth, visiting with hushed soft-

ness its dintless rocks; creatures full of pity, covering with strange and tender honour the scarred disgrace of ruin—laying quiet finger on the trembling stones to teach them rest. No words, that I know of, will say what these Mosses are. None are delicate enough, none perfect enough, none rich enough. How is one to tell of the rounded bosses of furred and beaming green—the starred divisions of rubied bloom, fine-filmed, as if the rock spirits could spin porphyry as we do glass? . . . They will not be gathered, like the flowers, for chaplet or love-token; but of these the wild bird will make its nest, and the wearied child his pillow. . . . And, as the earth's first mercy, so they are its last gift to us: when all other service is vain from plant and tree, the soft Mosses and grey lichen take up their watch by the headstone. The woods, the blossoms, the gift-bearing grasses, have done their parts for a time; but these do service for ever. Trees for the builder's yard, flowers for the bride's chamber, corn for the granary, Moss for the grave." This is exquisite writing, and the sentimentalist must be allowed some licence; but it is hardly correct to call Mosses "the first mercy of the earth," for they are by no means first, either in point of time or simplicity of structure. The poet's ecstasy, also, makes its appeal to the Nature-lover:

> "The tiny Moss, whose silken verdure clothes
> The time-worn rock, and whose bright capsules rise
> Like fairy urns on stalks of golden sheen,
> Demands our admiration and our praise,
> As much as cedar kissing the blue sky."

But our admiration and reverence are surely increased

by intimate knowledge, and the naturalist who hitherto has been content to admire the Mosses is hereby enjoined to study them. Such a study will yield an abundant reward.

In order to familiarize the reader with the life-history of a Moss, we propose to examine a type, the Common Cord-Moss, *Funaria hygrometrica*, of which some particulars are shown on Plate IV. This species, not more than ½ inch in height, grows in tufts on the ground, on walls, waste ground, and it seems particularly partial to soil on which rubbish has been burned. The tufts are of a bright green colour. Examining a single plant, we see that the leaves, which are pellucid—and although small in themselves, in comparison with other Moss plants of similar size, are large—grow in clusters near the ground. The stem branches, the branches being erect like the stem. The plant is attached to its substratum by threadlike root-hairs, or rhizoids. These absorb nutrient solutions, but are not true roots, such not being found in any of the Bryophytes. The leaves have midribs, are pointed at their tips, and are ovate in outline.

With the aid of the microscope, we are able to detect in a thin transverse section of the stem three fairly distinct zones of cells. The outer zone is the epidermis, for the most part one cell thick, and composed of small cells. The middle zone is the cortex, much thicker than the epidermis, and the young cells of this zone contain chlorophyll. In the middle is a well-defined strand of long cells with thin walls, which contain no chlorophyll. The probability is that the central strand is specialized for water-conduction. Microscopic ex-

amination of the leaves shows that the blades are only one cell thick, the cells being rich in chloroplasts; but the midribs are several cells thick, and include a strand of narrow cells in the centre. This strand passes into the cortex of the stem, but not into its central tissue. Perhaps these narrow cells pass on assimilated food and water. They seem to be the promise of a vascular sytem of conducting tissue, which, however, can be found fully developed only in higher plants. We shall see it in the Ferns and their allies. The leaves of the Mosses are evidently the principal carbon assimilators, and they are by no means dependent upon the work of the rhizoids for the absorption of water. The rhizoids doubtless do absorb a great deal of water and the needful mineral salts in solution, passing them upwards to the parts of the plant where they are needed; but the leaves can, and do, absorb much water through the thin walls of their cells. This being the case, an elaborate conducting tissue is not needed. It is a matter of common observation that Mosses growing in exposed situations, where they are subject to periods of drought—as, say, on a wall—seem to dry up and become lifeless in dry weather; but after a spell of rain, they become as green and vigorous as ever. They revive remarkably quickly, the phenomenon being due to the ease with which they can absorb water by means of their leaves. The Moss-collector takes advantage of this capacity. He knows that his specimens may be allowed to dry and remain apparently withered for months, but they recover freshness and form on being soaked in water.

In higher plants, we note that lateral buds always spring from the axils of the leaves—*i.e.*, from the angles

between the leaves and the stem. It is a peculiarity of the Mosses that lateral buds always rise from the stem at a point immediately *below* the leaves with which they are associated. The growth of all Mosses is apical, and is due to the divisions of a particular cell in the apex of the stem, or of the leaf, as may be.

In *Funaria*, the organs of sex, the antheridia and archegonia, occur on the same plant, which is on this account termed " monœcious (Gr. *monos*, single ; *oikos*, a house). In Plate IV., Fig. 11, is shown the tip of a male shoot. *a* marks the antheridia, which in Nature are about $\frac{1}{75}$ inch in length when mature; *b* indicates the paraphyses (see p. 111), which probably serve to hold water and secrete it when it is required by the antheridia. These latter are delicate organs entrusted with a vital mission, so they must be protected and served in accordance with their peculiar needs. In the same figure, at *d*, we have a drawing of a single spermatozoid, one of many liberated by the antheridia. It should be noted that the male shoots of *Funaria* attain a height of about $\frac{3}{8}$ inch, and that the leaves at its top form a crowded rosette, which appears reddish in the centre.

The female shoots rise as side-branches from the male stems; they are relatively small, and may number one or more per stem. The leaves at the tips of these shoots are arranged in a budlike manner, and enclose the archegonia. The fully grown archegonium is very like that found in Liverworts; in Plate IV., Fig. 15, we see a representation of one enlarged considerably—*k* is the neck along which a canal runs into the venter, *l*, and *m* is the egg-cell. When the archegonium is ripe for

fertilization, the cells terminating the neck draw apart, and open a way for the swimming spermatozoids liberated from a male shoot. The canal is oiled, as one might say, and the passage made smooth for the male elements by mucilage formed from broken-up canal cells, and sugar, a constituent of the mucilage, is used as a bait, which readily attracts the swarming spermatozoids. Water is essential as a medium for the fertilizing operation; a drop of rain is sufficient to carry the male elements from the discharging antheridia, and deposit them in easy reach of the archegonia.

What has so far been said in regard to *Funaria* concerns the sexual generation—*i.e.*, the gametophyte; this, we gather, includes the whole leafy plant, with its sexual organs and rhizoids. The asexual generation, or sporophyte, rises from the fertilized ovum, and is represented by the fruit, or sporogonium. The development of the sporophyte is to some extent shown in Plate IV., Fig. 16, where *n* is the embryo resulting from the fertilized ovum, *p* is the foot by which the sporophyte is attached to the gametophyte, and *o* is the calyptra (Gr., a veil) which is formed from the wall of the archegonium. This veil is ultimately ruptured by the growing fruit, and carried aloft on the stalked capsule on which it remains for some time as a protective sheath. The final stage is seen in Figs. 12, 13, and 14, of the plate already referred to, where *e* is the capsule containing spores, *f* is the capsule lid, or operculum, which is thrown off when the spores are ripe, and *g* is the *theca*, or head, supported on a stalk, or *seta*. The capsule, before throwing off the calyptra, is seen at *h*, and in Fig. 14 we have a capsule, minus calyptra and oper-

PLATE V.

PARSLEY FERN, OR ROCK-BRAKE (*Cryptogramme crispa*)

Fertile fronds above.

culum, showing its teeth, *i*. These teeth are in a double row; they form the peristome (Gr., *peri*, around; *stoma*, mouth). They are hygroscopic, and in wet weather close the mouth of the capsule, preventing the spores from escaping. When the air is dry, they turn back, open the mouth, and set the spores free—a very remarkable device to regulate spore-dispersal, and to insure that the spores are freed in dry condition, so that they may be dispersed far and wide by wind.

The capsule is at first green; it becomes brown at a later stage. The seta, or stalk, is reddish and sinuous. There is a remarkable feature in the base of the green capsule; stomata, or air pores, occur in its epidermis, and are related to a zone of cells containing chlorophyll. It is thus apparent that this part of the capsule performs a nutritive function, and shows that the sporophyte is not utterly dependent upon the gametophyte for supplies. We noted a similar feature in the Anthocerotes (p. 128), but it does not appear in other Liverworts.

The ripe spore contains chlorophyll and oil. When it germinates, on the strength of its reserves, it does not immediately produce an ordinary Moss plant. The product of its germination is seen in Fig. 17, Plate IV., in which *r* is the germinating spore and the protonema (p. 129) which issues from it; *s* stands for rhizoids. The spore at first produces two filaments, one of which becomes a rhizoid, while the other creeps over the ground, and sends out branches; the ordinary gametophytes, or Moss plants, arise from branches of this protonema, and a protonema formed from a single spore may yield a number of plants. This curious development certainly forms an excellent means of vegetative propa-

gation. It is worthy of note that protonema may be developed from various parts of a plant, as well as from spores; they are known to rise from leaves, stems, rhizoids, and fruits. Vegetative buds are thrown off by a number of Mosses. The alternation of generations in Mosses may be thus stated:

Sexual.

Spore
Protonema
Moss-plants
Antheridia Archegonia
Embryo

Asexual.

Embryo
Sporogonium {Seta, Capsule}
Spore

The Mosses are divided as a rule into four Natural Orders—the *Sphagnaceæ*, *Andreæaceæ*, *Phascaceæ*, and *Bryaceæ;* there are good reasons for including the *Phascaceæ* in the *Bryaceæ.* In regard to species, the Mosses far outnumber the Liverworts.

Sphagnaceæ.—The Bog Mosses, which grow on swampy ground, covering large tracts, and in some districts forming extensive and dangerous bogs. The bogs of Ireland, composed mainly of Bog Mosses, occupy many thousands of acres. The Order has but one genus, *Sphagnum;* this embraces a goodly number of species. All the Sphagnums have a remarkable capacity for absorbing and holding water, and it is for this reason that they are commonly drawn into the service of the horticulturalist. The remains of Sphagnum enter into the composition of peat. The colour varies; it is usually pale green, but may be yellow or almost red. The plants

branch extensively, and detached shoots become independent growths. The leaves have no midribs, and there is no trace of conducting tissue (p. 134) in the stems; such is not needed in a Moss that can absorb water through any part of its surface, and which grows in a practically aquatic environment. The Sphagnum spore, in germinating, produces at first a very short filament, the protonema, which quickly becomes a flat thallus very like the prothallus of a Fern, which we shall describe in the next chapter; it is from this flat thallus that young Moss plants develop. The sexual organs may occur both on the same plant, or the sexes are represented on different plants; they are formed on branches much like the sterile ones. The branches bearing antheridia are usually distinguishable by their bright colour; it may be dark green, red, or yellow. The leaves are close-set, and the antheridia occur singly in the axils of the leaves. The male organs liberate two-ciliate spermatozoids. The archegonia are found at the tips of short branches at the apex of the plant. The sporophyte, which arises from the fertilized ovum, has no true seta, yet it appears stalked; the stalk, however, does not rise from the embryo, but from the prolongation of the axis of the female shoot. The capsule is globular, and sits upon an expanded foot. The calyptra is not borne aloft, as in *Funaria*, but remains, after being ruptured, at the base of the sporogonium, as in the Liverworts. The capsule has a circular lid, which, when the spores are ripe, drops off in order to allow of their dispersal. The form of the protonema in the Sphagnaceæ suggests that this group of Mosses has arisen from an Hepatic ancestry. It seems probable

that the Mosses have been derived from Liverwort-like forms by mutations and natural selection. This is not easily demonstrable in the present state of our knowledge; but should such be the case, we may regard the Sphagnaceæ as forms intermediate between the ancestral Liverwort forms and the higher Mosses. The latter are a well-defined group, highly specialized according to their rank, and thoroughly fixed in their structure; they do not seem to lead to higher plants. They are another instance of a natural cul-de-sac, and, so to say, the last word of Nature in their particluar line of development.

Andreæaceæ.—Includes one genus, *Andreæa*, with few species, forming a link between the Sphagnums and the Bryaceæ. These Mosses are of small size, and their colour is very dark; they may be deep brown, and even blackish. They are among the first plant colonists of newly exposed rock-surfaces, to which they adhere, with much tenacity, by means of well-developed rhizoids. Their spore-capsules burst in a manner peculiar to the Order. Instead of throwing off an operculum, or lid, they split vertically, four slits being formed which do not reach the apex. The stems form branches; the leaves in some species have midribs. The sexes are represented on different branches.

Bryaceæ.—This Order embraces the great majority of Mosses; the genera are numerous, and we have not sufficient space to describe them here. The reader will already have learned some points of the Order from our study of *Funaria hygrometrica*. However, attention should be drawn to the protonema in the Bryaceæ; with very few exceptions it is filamentous, as described on p. 137, and in this respect these Mosses seem to be much

farther removed from the Liverworts than the Sphagnums, or even the Andreæaceæ; the latter, generally speaking, have a somewhat flat, thalloid protonema.

Perhaps the average amateur botanist is deterred from the study of the Bryophytes by the fact that a microscope is usually necessary for their examination, and that the determination of species is far from easy. However, there are no insuperable difficulties, and the student occupied with the flowering-plants in their seasons will find a fascinating winter occupation in the examination of Liverworts and Mosses. Specimens are to be found fully developed at a season when flowering plants are not active, and such as are gathered in the finer seasons are easily restored by soaking in water if they have been dried and saved for microscopic mounting in the warm comfort of a study in the winter months

CHAPTER VI

THE ARCHEGONIATES: II. PTERIDOPHYTES—FERNS, HORSETAILS, AND CLUB-MOSSES

THE leading characters of the Archegoniates were defined at the commencement of the last chapter, and in our study of the Liverworts and Mosses (Bryophytes) we saw that in their case the sporophyte is attached to and dependent upon the gametophyte throughout its life. In the Pteridophytes (literally, fern- or feather-plants), the sporophyte is " the plant " as ordinarily recognized. What is spoken of as " the plant " in the Bryophytes is the gametophyte, or sexual generation—the Liverwort thallus or the Moss-plant. The sexual organs of the Bryophytes are borne on " the plant," but in the Pteridophytes they occur on an inconspicuous *prothallus*, which arises from the spore on germination. It is called a pro*thallus* to differentiate it from the proto*nema* of Mosses; the latter is more or less, mostly more, threadlike, while the former is thalloid; the prothallus of the Ferns and their allies carries the sexual organs, whereas the protonema of the Mosses gives rise to buds which grow into Moss-plants that bear the archegonia and antheridia. The alternation of generations is distinctly marked in the Pteridophytes, but the sexual generation, the gametophyte, is never conspicuous. The prothallus does not attain great size; in no instance does

it "catch the eye," and it could hardly be noticed by any but a trained observer. The gametophyte of a Moss endures, even after it has formed the sporophyte, and the latter has done its work and decayed; but this is not so with the Pteridophytes. In their case the prothallus, after the fertilization of the ovum, and the launching of the sporophyte on its career, disappears. The sporophyte becomes independent at an early stage; it can "do for itself," for it has leaves, stems and true roots, and all the machinery essential for honest independence. But it lives for posterity as well as for itself, for it produces the spores from which new generations arise. These spores are borne in organs, known as *sporangia*, which occur on the leaves, or in close relation to them.

In the plants to be discussed in this chapter we must, on the understanding just arrived at, remember that it is the asexual sporophyte that attracts our attention in Nature; it is a highly organized plant, having true roots instead of mere rhizoids, as in the Mosses, and whereas in the latter we detect a mere trace of conducting tissue, in all the Pteridophytes this tissue is always present, and is elaborated into a vascular system which traverses stem, leaves, and roots. And, be it noted, the leaves are as advanced in structure as those of the average flowering plant.

The majority of the Pteridophytes produce spores that are all alike, and from these, when they germinate, prothalli arise bearing both male and female organs; but there are cases in which the sexes are represented on different prothalli. In some instances two sizes of spores are produced, in which event the larger (mega-

spores) give rise to female prothalli only, while those arising from the smaller (microspores) are invariably male. Plants producing spores of one size only are homosporous (Gr. *homos*, the same); those yielding both mega- and micro-spores are heterosporous (Gr. *heteros*, other).

The Pteridophytes embrace the following Classes of plants:

1. *Filices*—Ferns.
2. *Hydropterides*—Water Ferns.
3. *Equisetales*—Horsetails.
4. *Lycopodiales*—Club Mosses.

The Ferns are of ancient lineage. Their fossil remains indicate that they flourished exceedingly in very remote geological times, and of all the Pteridophytes they are unique in having been most successful in the struggle for existence right through untold ages to the present day. Indeed, it seems that they have thriven, and even increased, like Israel in Egypt, in spite of the "slings and arrows of outrageous fortune." This has not been so with their allies, the Horsetails and Club-Mosses, of which we have but a few existing survivors from a glorious past when they flourished "like the green bay-tree," for some of the extinct species were of majestic proportions.

With the assistance of some drawings and a few words of explanation, we can readily familiarize ourselves with the salient points in the life-cycle of a Fern. The Common Male Fern (*Lastrea Filix-mas*) grows in woods, shady places, and moist hedgerows, and is very common in Britain. It is found throughout Europe and Central and Russian Asia, from the Mediterranean to the Arctic

PLATE VI.

COMMON POLYPODY FERN (*Polypodium vulgare*).

regions; it also occurs in the Andes and in Africa. As will be seen from Fig. 43, it has a short but stout stem, which gives an appearance of being much thicker than

FIG. 43.—MALE FERN (LASTREA FILIS-MAS). MUCH REDUCED. *a*, *b*, Apex and base of stem; *c*, *c*, young fronds showing circinate vernation

it actually is, because it is covered with the bases of past leaves. Note the crozier-like appearance of the young leaves (*cc*); this is known to the botanist as " circinate vernation," and is characteristic of the Ferns.

The expanded leaves are very handsome; they grow to a length of from 2 to 3 feet, and form a circular tuft. It is usual to call the leaves of Ferns "fronds." In the Male Fern they are "compound," which means that the leaf-blade is divided into what appear to be many leaves, but are really leaflets. The leaflets of Ferns are called *pinnæ* (L. *pinna*, a feather), and the frond of the Male Fern is pinnate (shaped like a feather), the pinnæ forming two rows, one on either side of a stalk, termed the *rachis* (Gr. *rachis*, the spine). The pinnæ themselves are deeply lobed—*pinnatifid*—and in some specimens they are completely pinnate, in which event the frond is described as *bipinnate*. Two further points are worthy of remark in regard to the leaves; they taper to a point at the apex, and the pinnæ become shorter towards the base; again, the *rachis*, like the main stalk, is furnished with brown chaffy scales or hairs, which even extend to the veins of the pinnæ. In the mature plant the roots are all "adventitious," or casual; they proceed from the bases of the leaves: the main root developed by the embryo always disappears at an early stage of growth.

Such are the general external characters of the Male Fern. If we examine well-grown fronds in the late summer or autumn, we shall find brown *sori*, clusters of sporangia, arranged as in Fig. 44, *B*, on the under surface or back of the pinnæ; they are numerous over about two-thirds the length of the frond, but do not as a rule appear at its base; if they do so appear, they are scattered and not regular in arrangement, as on the higher part of the leaf. Close examination will disclose the fact that each cluster of sporangia—*i.e.*, each *sorus*—is protected by a membrane, which, in our subject, is

kidney-shaped; this is termed the *indusium*. Thus, we understand that each brown point found on the under surface of the frond is a *sorus*, consisting of a cluster of sporangia protected by the indusium. We need the aid of a powerful hand-lens to make out the sporangia; a goodly number being clustered in each sorus, they

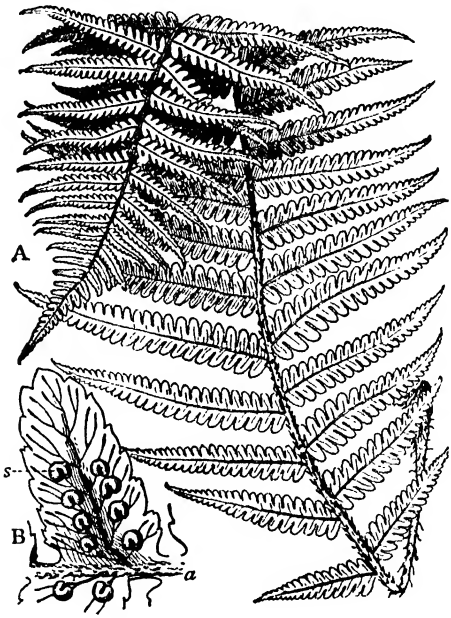


Fig. 44.

A, Frond of male fern; *B*, underside of a fertile pinna; *a*, rachis; *s*, sorus. Enlarged.

are necessarily small. Now, the sporangia yield a great number of spores, and we may rest assured that if every spore produced by a single Male Fern were permitted to yield a complete plant, the species would soon be uncomfortably numerous; but " there's many a slip 'twixt the cup and the lip " in the plant realm, and so

many are the risks and chances to which the multitudinous spores of the Male Fern are submitted that comparatively few of them are allowed to develop into mature plants.

The spores are, for the most part, dispersed by wind, and such as drift on to a suitable substratum germinate.

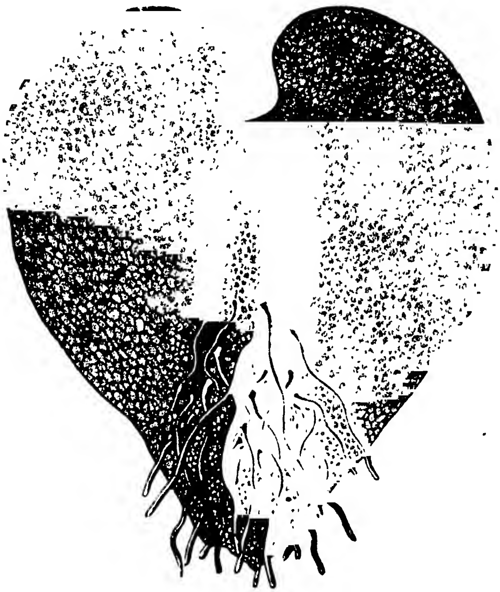


FIG. 45.—PROTHALLUS OF FERN, UNDER-SURFACE. × 25.
Archegonia occur towards the apex, and root-hairs and antheridia near the base.

The product of germination is a prothallus, and the student who desires to investigate this interesting stage in the development of a Fern is advised to scatter some spores on the surface of soil in an ordinary flower-pot. The soil must be kept moist, and the pot should be covered with a sheet of glass to insure a moist atmosphere; in the course of about a week the spores will

germinate. The prothallus of the Male Fern at maturity may be nearly half an inch in diameter; it is green, flat, and heart-shaped, and is attached to the soil by means of rhizoids growing from its under-surface. An enlarged drawing of a prothallus is seen in Fig. 45, which shows that the sexual organs occur on the under surface, the archegonia towards the apex, and the antheridia towards the base, the former being confined to a thickened central part called the cushion. These organs are small, and we must use the microscope if we would observe their structure; the antheridia are little hemispherical outgrowths; each one produces about twenty coiled spermatozoids, with numerous fine cilia at one end (see Fig 46). In the presence of water these active male elements are liberated; they work their ways through the water ciliated ends foremost, and wriggle by a devious course towards the attractive archegonia. Fig. 47 shows an archegonium greatly enlarged and ready for fertilization; note the neck, *n*, and the ovum, *o*; the contents of the canal cells become mucilaginous, they swell and force the neck open, and a drop of mucilage, *m*, is extruded at the mouth. It seems that the archegonia produce malic acid, which diffuses in the water, and constitutes an attraction to the spermatozoids. One of the latter works its way into the drop of mucilage, *m*, and swims slowly through the mucilage in the canal until it reaches the ovum, with which it fuses. So fertilization is effected. More than one male element may get into the canal, but it is questionable if more than one is permitted to fuse with the ovum. The embryo arising from the fertilized ovum is dependent upon the prothallus for a time, but the nutrient sub-

stances in the latter are rapidly exhausted; the growing sporophyte first develops a root, then a leaf, and soon becomes quite independent of its parent.

Seeing that the gametophyte of a Fern is dependent upon water in the process of fertilization, it may be safely termed "amphibious"; to a certain extent it is a creature of the water, but to a greater extent it is a

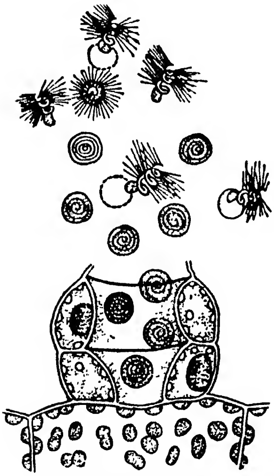


FIG. 46.—RIPE ANTHERIDIUM OF MALE FERN. SPERMATOZOIDS ESCAPING. × 350.

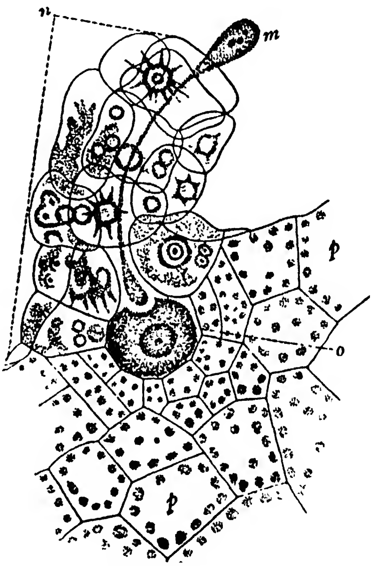


FIG. 47.—ARCHEGONIUM OF MALE FERN PREPARED FOR FERTILIZATION. × 350.

p, Cells of prothallus; *n*, neck; *m*, mucilage extruded from canal; *o*, ovum.

creature of the land. This particular water requirement of a Fern indicates the aquatic ancestry of these land plants, and the prothallus represents a stage through which the Ferns have passed in the course of their evolution. The sporophyte, the Fern-plant, so soon independent of the gametophyte, is a remarkable demonstra-

tion of a further advance whereby plant-life, originally aquatic, has become adapted to terrestrial conditions.

We have already referred to the existence of true conducting, or vascular, tissues in the Pteridophytes, and these are well seen in the sporophyte of the Male Fern. In the young sporophyte this tissue is represented in the stem by a central cylinder, called a *stele*, but as the plant advances this central stele gives rise to a branching network of steles, as shown in Fig. 48, with steles branching into the leaves. These vascular strands are woody; they strengthen the plant so that it may preserve a degree of upright dignity; and it is along their channels that water with dissolved mineral salts, absorbed by root hairs, is conducted throughout the plant, and, moreover, it is through them that the products of plant chemistry pass to parts where they are required. The entire plant may be likened to a house of many rooms, with water "laid on" in every apartment, and in which there is a system of communication of the parts with the whole. The "house" is occupied by myriads of microscopic protoplasts with definite occupations. Moreover, there is a system of venti-

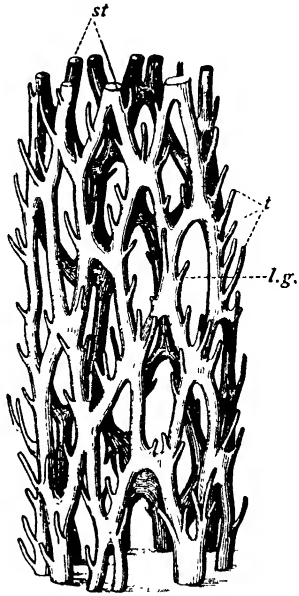


FIG. 48.—VASCULAR SYSTEM OF MALE FERN. ENLARGED. *st*, Leading steles of stem; *l.g.*, leaf-gap corresponding to insertion of a leaf; *t*, steles branching into leaf.

lation and overflow. If there is to be a circulation of sap, some water must be allowed to evaporate from the leaves in order that water laden with fresh materials may take its place. Full provision is made for this evaporation. On the under-surface of a Male Fern leaf the epidermis is pierced with little pores, or stomata, as shown in Fig. 49, so constructed that they may open or close to facilitate or prevent evaporation. Usually they are open on a hot day, when much water passes out of the leaves in the form of vapour. But the stomata serve other purposes; through them carbon dioxide is admitted and passed on to the busy alchemists, the chloroplasts; and through them, too, superfluous oxygen, and also carbon dioxide resulting from internal combustion, pass out into the air. In the Pteridophytes the vascular system ramifies throughout the plant, through roots, stems, and leaves, and the sporophyte is in every respect furnished for independence.

It may be well at this stage to contrast the life-cycles of a Moss and a Fern:

	Moss.		*Fern.*
	Spore		Spore
	Protonema	Sexual	Prothallus
Sexual	Moss-plant	Sexual	Antheridia — Archegonia
Sexual	Antheridia — Archegonia		Fertilized Ovum
	Fertilized Ovum	Asexual	Embryo
Asexual	Embryo	Asexual	Sporophyte (Fern-plant)
Asexual	Sporogonium	Asexual	Sporangium
Asexual	Spores	Asexual	Spores

The Ferns may be divided into eight families, as follows:

1. *Hymenophyllaceæ.*—These are the Bristle or Filmy Ferns, of which about 200 species have been distinguished. They are as a rule extremely delicate, and grow only in the presence of abundant moisture. The blades of the fronds as a rule are only one cell thick, but there are a few exceptions. This thinness of the

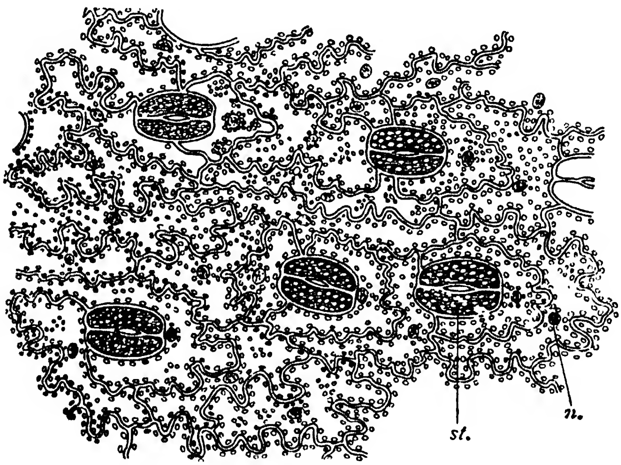


FIG. 49.—MALE FERN. PORTION OF EPIDERMIS FROM UNDER-SURFACE OF A LEAF. × 105.

st, Stoma; *n*, nucleus of cell.

leaves renders them pellucid, and gives them a filmy appearance. Stomata are not present, except in the New Zealand genus *Loxsoma*. The great majority of the species are tropical; some of them occur as epiphytes —*i.e.*, they grow upon other plants. Two species are found in Britain—the Filmy Fern, *Hymenophilum tunbridgense;* and *H. peltatum* (Desv.). The former is of frequent occurrence in moist, rocky, and shady situa-

tions; it grows in mosslike patches, and revels in a situation where it is sprayed by the falling waters of a cascade. The uninitiated usually mistake this species for a Moss. The fronds are pinnate, about 2 inches long, with slender stems. The Killarney Fern, *Trichomanes radicans*, is found principally in the south of Ireland, in the neighbourhood of waterfalls. The sporangia, in the Hymenophyllaceæ, are placed at the margins of the fronds on the free ends of veins.

2. *Polypodiaceæ.*—A very numerous division, including about 3,000 species, all of what may be termed of the " modern " type, being the most specialized of the Ferns. The Male Fern, which we have discussed at some length, is a fair type of the division. The stalked sporangium is a character persistent throughout, but the arrangement of the sori on the back of the fronds is varied in different tribes. Out of this numerous family only about forty species are found in Britain. It is impossible in the space at command to give even the roughest outline of the various tribes and genera.

Cyatheaceæ.—About 200 species have been distinguished, none of which are British. These Ferns are of large size, some of them being " Tree-Ferns " attaining a height of between 30 and 40 feet; they occur in the tropics.

Gleicheniaceæ.—Embraces two genera, *Gleichenia* and *Stromatopteris*, the latter having but one species, and the former about twenty-five. They are all tropical and subtropical Ferns.

Schizæaceæ.—Over sixty species in five genera; nearly all tropical. Includes some small and delicate

Ferns, but in the genus *Lygodium* there are species with twining fronds which grow to considerable length. Hooker says that the New Zealand climbing Fern, *L. articulatum*, has fronds which may grow to a length of nearly 100 feet.

Marattiaceæ.—A family which evidently embraced abundant species in remote geological times, and was then probably dominant among the Ferns; now it is reduced to twenty-five species, which are found only in tropical and subtropical regions.

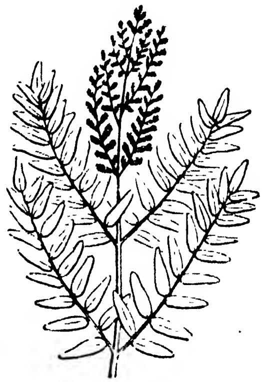


FIG. 50. — FROND OF ROYAL FERN BEARING SPORANGIA.

Osmundaceæ.—Only eleven known species; one confined to South Africa, four mostly to Australasia, and the remaining six are found mainly in the temperate regions of the Northern Hemisphere. One species is found in Britain—the beautiful Royal Fern, *Osmunda regalis* (Fig. 50)—which, alas! is so much sought after by collectors that it is becoming rarer every year. Some of the fronds bear no sporangia, but those that do are so covered with them as to appear like spikes of flowers arranged in a panicle—hence the common misnomer, "Flowering Fern."

Ophioglossaceæ.—Twelve species, two of which occur in Britain—the Moonwort, *Botrychium lunaria*; and the Adder's Tongue, *Ophioglossum vulgatum*. The prothallus is tuberous, with the sexual organs sunk in its tissue; it is always subterranean, and consequently has no chlorophyll; to make up for this loss, it is

saprophytic and inhabited by the hyphæ of a Fungus, which evidently contributes to the sustenance of the plant.

HYDROPTERIDES—WATER FERNS.

These are more or less aquatic plants, allied to the Ferns, occurring either in water or in marshy places. They are heterosporous; the megaspores are borne singly in megasporangia, and the microspores are produced in quantities in microsporangia. The sporangia are not found on the under surfaces of fronds, but occur at their bases in special receptacles. The megaspores develop into female prothalli, whereas the microspores produce tiny, few-celled male prothalli from which spermatozoids are liberated. There are two families—the *Marsiliaceæ*, with two genera, *Marsilia* and *Pilularia*; and the *Salviniaceæ*, also with two genera, *Salvinia* and *Azolla*. The Salviniaceæ embrace nine species; *Salvina* occurs in Southern Europe; it has a horizontal stem, which lies on the surface of water, and to which are appended floating and submerged leaves; the latter are filamentous, and hang down in the water; they absorb nutrient substances in solution, and are substitutes for roots. The sporangia lie on the submerged leaves, at their bases. *Azolla* is mostly tropical. Of the Marsiliaceæ there are thirty-five species, thirty-two being embraced by the genus *Marsilia*. The genus *Pilularia* is represented in Britain by one species, *P. globulifera*, the Pillwort, or Pepper-Grass. It is a small creeping plant with grassy leaves, occurring in marshy ground and in the shallow margins of lakes and pools. The stem is slender, almost threadlike; it sends down

tufts of fibrous roots from its nodes, and the bright green leaves, or fronds, about 2 or 3 inches long, also rise from the nodes in tufts. They display crozier-like curling (circinate vernation) in their young condition, but at maturity they are erect. The fructifications (sporocarps) are globular, about $\frac{1}{6}$ inch in diameter; they appear like little pills attached by very short stalks to the bases of the leaves. These sporocarps are four-chambered, and in each chamber there is a single sorus containing both mega- and micro-sporangia. The spores are in due course liberated; they develop into male and female prothalli. This plant is often overlooked; it ranges in Europe north of the Alps; it is rare in Ireland, but widely distributed over Scotland and England.

In these heterosporous plants we detect a step in the direction of that marked elaboration of sex exhibited in the pistil and stamens of flowering plants; but this step is better demonstrated in other Pteridophytes, as we shall see, and there is good reason to believe that the Water Ferns are a side-line of plant-life, leading to no forms higher than themselves..

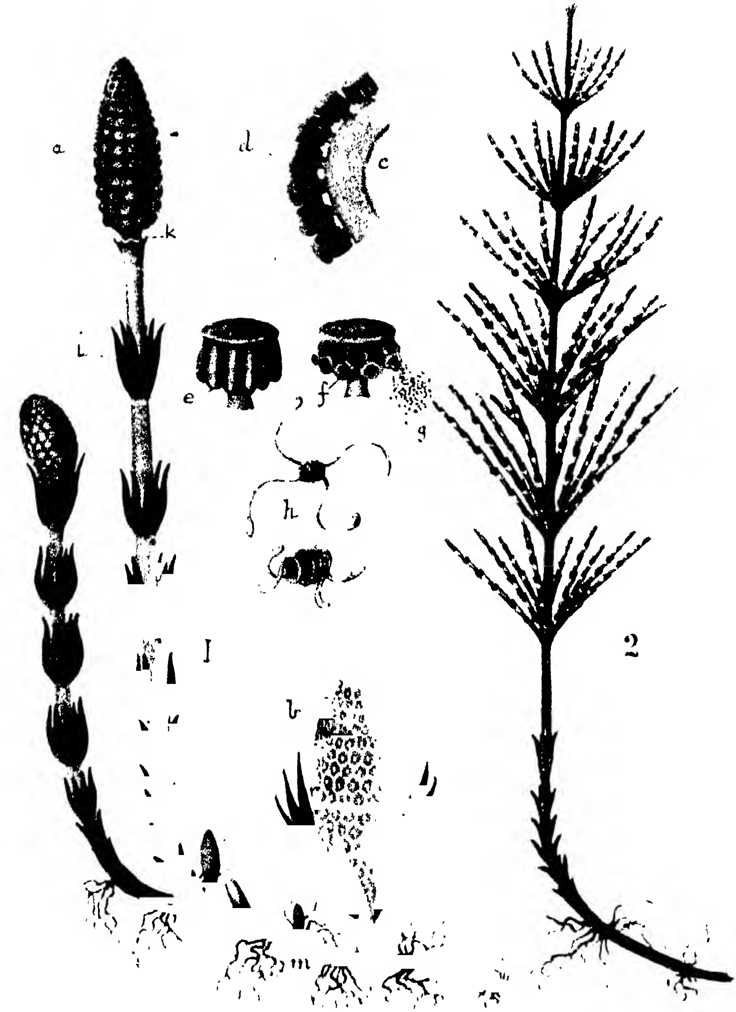
Equisetales: Horsetails.

Plants of this group are not likely to be overlooked; they are familiar even to children, and the agriculturalist knows them as pests which are none too easy to eliminate once they have obtained a local habitation in his ground. *Equisetum arvense*, for example, develops a branched rhizome—*i.e.*, an underground stem—that penetrates to a depth in the soil at which it usually succeeds in

avoiding the ploughshare or the spade. Giant Horsetails existed in remote geological times, when many species flourished; but the family's day of glory has departed, and the ancient aristocracy is now represented by between twenty and thirty species, all included in the solitary genus *Equisetum*. The greatest existing member of the family, *E. giganteum*, grows in tropical America; it attains a height of about 30 feet, but it has a very slender stem, and has to depend upon the support of neighbouring vegetation. The smallest known species is *E. scirpoides*; its stems are about 6 inches long and $\frac{1}{25}$ inch in diameter. Eleven species have been recorded in Britain, and of these *E. maximum* (*Telmateia*, Ehrh.) is the most impressive; its vegetative shoots rise to a height of over 6 feet, and their graceful branchings and delicate colouring render them very attractive. The spore-bearing shoots appear solitary in the spring; they are not more than 10 inches high, and by the time the vegetative shoots appear they have done their duty and withered away. This species occurs in marshy, wet, and shady places in temperate Europe, in Russian Asia, and North America.

All the species display a family likeness. The stems are hollow, jointed, furrowed, and erect; the leaves are much reduced; they form sheaths at the joints of the stems; branches, when present, occur in whorls at the leaf-sheaths. *E. arvense*, the Common or Field Horsetail (Plate VII.), an almost cosmopolitan species, may be taken as a type. The rhizome (Fig. 1, *m*) penetrates 2 or 3 feet beneath the surface of the soil; it possesses leaf-sheaths, and sends out adventitious roots from its nodes; it also produces tubers from which new plants are

PLATE VII.



CORN-HORSETAIL (*Equisetum arvense*)

1. FERTILE SHOOTS
   - *a.* Spike bearing sporophylls
   - *b.* Younger spike, enlarged
   - *c.* Cross-section through spike
   - *d.* Sporophylls
   - *e.* Sporangia (closed)
   - *f.* Sporangia (open)
   - *g.* Spores
   - *h.* Spores, enlarged, with four elaters, open and closed
   - *i.* Leaf-sheath
   - *k.* Ring
   - *m.* Horizontal rhizome
2. VEGETATIVE SHOOT

vegetatively developed. Two kinds of aerial shoots rise from the rhizome, the one kind being fertile and the other vegetative. The fertile shoots appear early in spring; they are almost colourless, each one is surmounted by a spore-bearing cone, and when the spores are shed it dies down. It is a part of the economy of the plant to waste no energy on shoots that have served their purpose. The vegetative shoots appear after the fertile ones have withered, and, unlike the latter, they are branched, and the branches are of a deep green colour. The fertile shoots reach a height of 6 or 8 inches, whereas the sterile ones may attain a height of from 1 to 2 feet. It is the duty of these green shoots to assimilate carbon, which is done principally by the branches, all these having stomata and chlorophyll, and to manufacture food material in excess of immediate requirements, the excess being stored in the rhizome, and forming a reserve enabling the fertile shoots to do their special work in the following spring without troubling about the commissariat. The fertile shoots have no chlorophyll or stomata. The outer cell-walls of the epidermis of the shoots contain silica, which makes the surface hard. It does not happen in every species that the fertile shoots are destitute of vegetative capacity, as in *E. arvense;* in some species, for example, the Wood Horsetail, *E. sylvaticum*, spore-bearing cones occur at the summits of ordinary vegetative stems.

Still referring to Plate VII., we have in Fig. 1 a drawing of fertile shoots of *E. arvense*, in which *i* is a leaf-sheath, and *a* and *b* are cones composed of specialized leaves called "sporophylls." These sporophylls bear sporangia (*e*, *f*) on their under-surface. When ripe, the sporangia

open and discharge the spores (*g*). In *h* we see the spores greatly enlarged, and observe that they each bear four curious arms, or elaters. The elaters are hygroscopic; in the presence of moisture they coil up (see drawing), but when dry they expand. These changes set the spores in motion. It is conjectured that the elaters serve two purposes; in the first place, they are

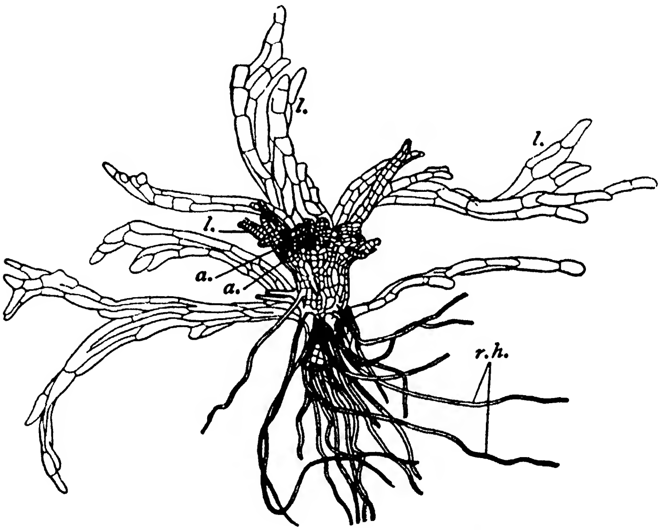


FIG. 51.—FEMALE PROTHALLUS OF EQUISETUM MAXIMUM, SEEN FROM BENEATH. × 30.

a, *a*, Archegonia; *l*, *l*, lobes; *r.h.*, root-hairs.

said to help in the opening of the sporangium; in the second, they bring about entanglement of the spores, and thus insure that they fall to the ground and germinate in close proximity. This is essential, as the prothalli rising from the spores are as a rule unisexual, and if fertilization is to be secured the sexes must be within easy reach of each other. Fig. 51 is a drawing of

a female prothallus of *E. maximum*, enlarged about 30 diameters, indicating the position of the archegonia. The female prothalli are usually larger than the male. The antheridia are very simple, and the spermatozoids are very similar to those of Ferns (p. 150). Fertilization can take place only in the presence of water. The sporophyte—*i.e.*, the Horsetail "plant," soon becomes independent of the prothallus.

The Horsetails are a very distinct family; they are not likely to be confused with the Ferns, yet there is a striking resemblance between the reproductive organs, and especially the spermatozoids, of the two families. On account of this resemblance it is suggested that both Ferns and Horsetails had a common origin, from which the two became more and more divergent in their evolution.

Lycopodiales: Club-Mosses.

The Club-Mosses, by reference to which we conclude our outline of the Pteridophytes, are not Mosses in the strict sense of the term; it is only deference to popular usage that permits the retention of their misnomer. By way of general definition, we may say that the Lycopodiales are plants that usually have long branching stems, bearing relatively small leaves; they produce spores, not seeds, and the spores are developed in sporangia borne in the leaf axils, or on the upper surfaces of the fertile leaves, which in numerous instances occur in aggregations of the nature of cones. There are homosporous and heterosporous (p. 144) families. Of course, there is the usual alternation of generations. Another feature consistent throughout the group is the production

of spermatozoids possessing two cilia, which are thus different from the multiciliate male elements of the Ferns. Existing species are arranged into four families —the *Lycopodiaceæ*, *Psilotaceæ*, *Selaginellaceæ*, and *Isoëtaceæ*; two other families, the *Lepidodendraceæ* and *Sigillariaceæ*, occur only in fossil forms.

Lycopodiaceæ.—This family includes those species which have gained popular recognition, and have secured the appellation, "Club-Mosses." Between 90 and 100 species have been distinguished, and five of them are found in Britain. The Common Club-Moss, *Lycopodium clavatum*, sometimes called "Stag's-Horn" Moss, is generally distributed over Britain on heaths and hill-pastures; its range extends from the Pyrenees and the Alps to the Arctic regions, and it is found in North America. The hard creeping stems, with forked branchings, are covered with small awl-shaped leaves; forked roots are sent into the ground from the under side of the stem, while from above leafy branches ascend into the air. Conelike aggregations of sporophylls (spore-leaves) occur at the tips of the erect shoots. The sporophylls are somewhat broader than the ordinary leaves; they bear kidney-shaped sporangia, one at the base of each, on the upper side. The sporangia are relatively large, very much larger than those produced by Ferns. The Fir Club-Moss, *Lycopodium selago*, also occurs in hill-pastures in Britain; it ranges in the cold and temperate countries of both hemispheres. This species is peculiar in that its forked stems are always erect, and there is no distinction between the spore-bearing and sterile parts of the shoots. *L. alpinum* is rare in Southern England; but it is found in mountain pastures from the

Alps to the Arctic regions, and is abundant in Scottish and Irish mountains. The spores produced by the Lycopodiaceæ are of one size; they give rise to various forms of prothalli, which in some instances are small, colourless, tuberous structures growing underground, and are saprophytes accompanied by a fungus. Male and female organs occur on the same prothallus, the antheridia being sunk in the tissue, while the archegonia rather resemble those of Ferns.

Psilotoceæ.—A family with two genera. *Psilotum* grows on tree-trunks and branches in the tropics. Its stem is angular and forking; its leaves are much reduced, and scalelike. It is a delicate plant, and has no roots. *Tmesipteris* is found in Australia and New Zealand; it has lengthy trailing stems, furnished with pointed leaves; it also is an epiphyte.

Selaginellaceæ.—The largest family of the group, but its 500 species are all included in the one genus—*Selaginella.* The majority of the species are tropical; one is abundant in the European Alps, *Selaginella helvetica* (Fig. 52), and *S. selaginoides,* or *spinosa,* called the "Lesser Club-Moss," or "Prickly Mountain-Moss," is found in the North of England, in Wales, Scotland, and Ireland, in wet stony places, and in boggy places by mountain-streams. An enlarged drawing of a fertile spike of this species is reproduced in Fig. 53. This solitary British representative of the Selaginellas differs from most of its relatives in having leaves arranged *round* the stem; the majority of the species produce shoots with four rows of leaves, two of them arranged one on either side of the edges of the stem, and two on either side of a middle line on the upper surface of the

stem, the latter rows consisting of overlapping leaves that are smaller than those of the other two side rows. The arrangement of the leaves gives the shoots a flattened appearance. Some species of tropical Selaginellas are cultivated in hothouses, and called "Lycopodium," another instance of a popular misnomer. Among these one of the most common is a native of Madeira, the

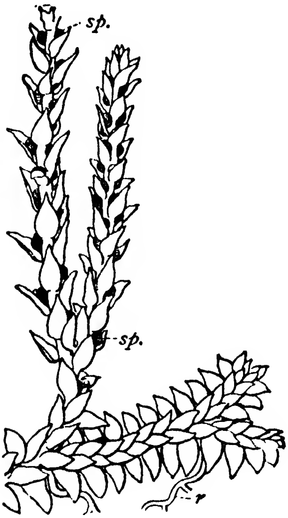


FIG. 52.—SELAGINELLA HELVETICA. SLIGHTLY ENLARGED.
Stem with rhizophore (r) at base; two fertile spikes ascending; *sp*, sporangia.

FIG. 53.—FERTILE SPIKE OF SELAGINELLA SPINOSA. × 1½.

Azores, and South Africa; it goes by the name of *Selaginella Kraussiana* (see Fig. 54). It has a repeatedly forked creeping stem, with numerous small leaves arranged according to the above description. A feature of the leaves is a small outgrowth of membranous texture, arising from the upper surface, almost at the base; it is distinctly seen on young leaves, but withers as they

become mature. This outgrowth is called the *ligule* (literally, a tongue), and it is a regular feature throughout the genus. In the figure, *r* points to the *rhizophores* (root-bearers) arising from the stem; these seem like roots, for they are destitute of leaves, and colourless; they reach down to the soil, and it is on touching it that they give rise to true rootlets, which branch from them

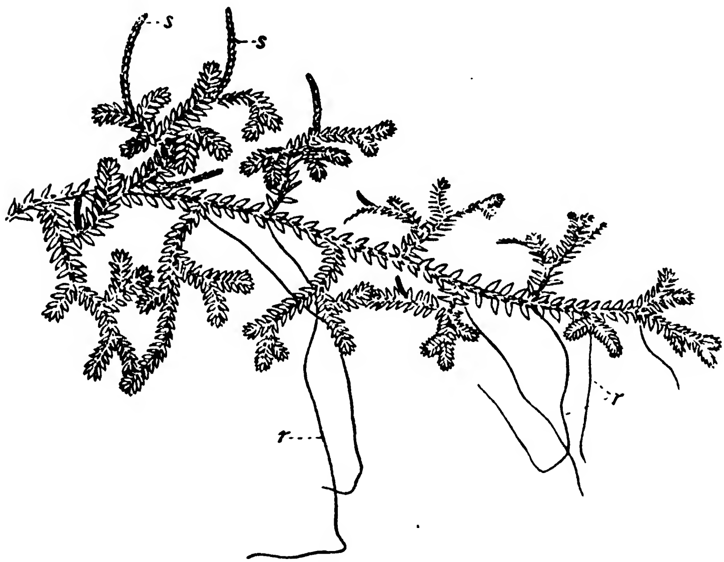


FIG. 54.—SELAGINELLA KRAUSSIANA.
r, Rhizophores; *s*, spikes.

and penetrate the ground. Certain branches are erected from the creeping stem, and bear the fruiting spikes, or cones (Fig. 54, *s*). The leaves of the cones are sporophylls; they bear the sporangia in their axils. The sporangia are slightly stalked, and of two kinds—microsporangia and megasporangia. The former contain a great number of microspores; the latter have only four

megaspores in each, and are the larger. Both kinds occur in the same cone.

Very little water is necessary to enable the microspores to germinate. The development is illustrated in Fig. 55, from which it will be seen the prothallus consists of a single prothallus cell, and an antheridium in which spermatozoids are formed. The spermatozoids are exceedingly small; they are furnished with two cilia, with which the water is lashed in swimming. It is a noteworthy fact that the megaspores begin their germination while they are still in their sporangia, but it is not completed until they fall to the ground, yet before this happens a small prothallus and an archegonium may be formed *within* the spore. After reaching the ground the

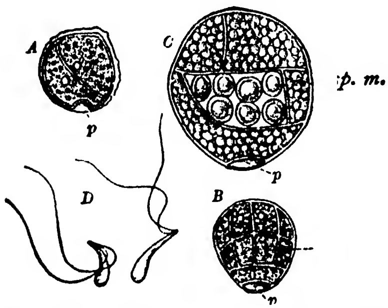


FIG. 55.—GERMINATING MICROSPORES OF SELAGINELLA.

A, Early stage, × 290; *p*, prothallus-cell; *B*, farther advanced stage, × 290; *p*, prothallus-cell; *c*, cells which will produce spermatozoids: *C*, mature stage, × 640; *sp.m.*, sper-

is ruptured, the prothallus grows to a very limited extent, and more archegonia appear round the original one. An archegonium ripe for fertilization is seen in Fig. 56. Fertilization is effected by swimming spermatozoids, which are attracted by archegonia that are sufficiently near. The male elements are so small that the veriest film of water on the surface of damp ground is sufficient to enable them to swim freely. The fertilized ovum becomes an

embryo, which in due course becomes an independent Selaginella plant.

Isoëtaceæ.—Plants with short, usually unbranched, fleshy stems, on which alternating whorls of fertile and barren, awl-shaped leaves are borne; the leaves are fleshy, and the roots have forked branches. They grow on very damp soil or submerged in water. The family includes the one genus *Isoëtes*, with about fifty species, which are found in different parts of the world. Three species occur in Britain, and *Isoëtes lacustris*, one of these three, known as the European Quillwort, or Merlin's Grass, is a good type of the genus. Its stem is tuberous and very short, almost globular in form. The leaves rise from the crown of the stem; they are from 2 to 6 inches long, awl-shaped, and dilated at their base. Above the base they are quadrangular. This curious plant grows in mountain-pools and shallow lakes in North Britain. At a cursory glance it might easily be mistaken for the Shore-Weed, *Litorella lacustris*, a flowering-plant of the Plantain family, or even for the Water Lobelia, *Lobelia dortmanni*. In a pit on the inner side of the dilated base of each leaf a single bulky sporangium is placed, and above it is found a membranous, triangular ligule. The plant is heterosporous. The numerous microspores are developed in microsporangia, which are found on the inner leaves. The megasporangia are on the outer leaves; each one con-

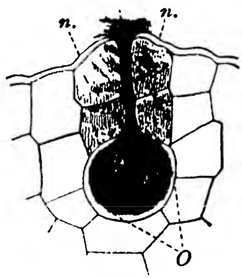


FIG. 56.—ARCHEGONIUM OF SELAGINELLA READY FOR FERTILIZATION. × 500.

O, Ovum; *m*, mucilage in canal; *n*, cells of neck.

tains several megaspores. The development of the spores and the sexual generation, the gametophyte, is much like that of *Selaginella*. The Isoëtaceæ, as we have them to-day, seem to be survivors of an ancient group of plants which was numerous in earlier geological periods. The spermatozoids generated by the antheridia are multiciliate, as in the case of the Ferns, and it is a debatable point as to whether the Isoëtaceæ are not more nearly related to the Ferns than to the Club Mosses, with which they are usually grouped.

We have now concluded our rapid résumé of the salient features of the Pteridophytes. The bald facts that have been stated may not stand for much in the mind of an unimaginative person, but to the intelligent and thoughtful reader, who reads between the lines, they will appear pregnant with suggestion, and will not fail to arouse wonder and awe. For the facts represent the patient and majestic progress of plant-life. All the earliest plants were aquatic and of the simplest type. Advanced aquatic plants have some complexity of structure, but it was in the invasion of the land and the determination to colonize it that greater complexity was demanded. The Pteridophytes in their sexual generation, in which water is necessary for the progress of the ciliated male elements and the act of fertilization, betray their aquatic ancestry. In the development of a Fern, we may say that we have evolution proceeding before our eyes. The utter dependence of the asexual generation upon the sexual in the Moss group does not exist among the Ferns. In the Mosses the sexual generation is " the plant "; but the asexual sporophyte

is the Fern-Plant, and it early becomes independent of the gametophyte. The Fern is more of a land plant than the Moss, and it stands for a distinct advance in the progress of land conquest by plant-life. But if the Pteridophytes generally display advance upon the Bryophytes, it is equally true that there exists abundant evidence of advance in their own ranks. The homosporous forms have prothalli of relatively large size, upon which in most instances male and female organs grow in association. There is evidence of the separation of the sexes upon different prothalli in these forms, but it is significant only as a mild attempt at a separation which is successfully achieved in the heterosporous forms. We are reminded of the old legend, which has it, in regard to man and sex, that the original men were unsexual, but, in course of time, each was cleft in twain by the gods, one half becoming male and the other female. In the plant realm we have asexual plants, sexual plants without sex-differentiation, and plants in which such differentiation becomes more and more pronounced. The heterosporous Pteridophytes are a distinct advance upon their homosporous allies. In the latter, sex-distinction does not appear in the sporophyte, it becomes evident only in the sexual generation; but in the former, the sporophyte—*i.e.*, "the plant"—bears female megaspores and male microspores, so that sex is apparent in the heterosporous forms in both generations. The well-nourished megaspore illustrates the emphasis which Nature has learned to place upon a sex which has to do so much for posterity. The facts brought out in relation to the partial germination of the megaspores of *Selaginella*, while still *in situ*, are extremely significant;

they are an anticipation of the seed-bearing plants in which the ovules are fertilized, and the embryo is formed and supplied with some reserve food in the seed itself, all being accomplished before the seeds are shed. The microspores of the same plant correspond to the pollen grains of the seed-plants, and the sporangia in which they are formed to the pollen-sacs.

Along with the greater sex-differentiation we observe a corresponding reduction of the prothallus, which in *Selaginella* has lost the power of independent nutrition in the female, and in the male has but a single vegetative cell. Herein we see a further determined effort towards independence of the sporophyte. In the conquest of the land, plant life has evidently advanced cannily. It has felt its way, and even groped in the dark; but from the evidence before us it certainly did not "burn its boats behind it" until it could assuredly get on without them. The gametophyte was first aquatic, then amphibious, and finally, as we shall see later, terrestrial, and in each stage of its advance it became more reduced vegetatively, and more specialized for sexual purposes. In this advance the sporophyte increases mightily, and in the end asserts and justifies its independence.

We must also insist upon the importance of the development of a vascular system in the Pteridophytes; it stands for adaptation to terrestrial conditions, and an elaboration of structure to meet their requirements. If a plant is determined to live an upright and partially aerial existence, it must strengthen itself against the wind, and, moreover, provide water and ventilating systems that are equal to its needs.

PLATE VIII.

MARSH MARIGOLD (*Caltha palustris*),
ORDER *RANUNCULACEÆ*.

1. Essential organs
2. Longitudinal section of ovary
3. Single carpel dehiscing
4. Fruit

CHAPTER VII

PHANEROGAMIA: FLOWERING PLANTS

It is customary to call flowerless plants "Cryptogams" (Gr. *kryptos*, concealed; *gamos*, marriage). Perhaps the term is not so appropriate as it was erstwhile considered to be, for the process of fertilization in the flowerless plants is now traceable by means of the microscope, and we know a good deal about it. All the plants we have considered up to the present point are flowerless, and, according to "use and wont," we speak of them as "cryptogamic"; but we have arrived at that stage in our story of plant-life at which we have to discuss the flowering plants, or Phanerogams (Gr. *phaneros*, visible; *gamos*, marriage). In such the sexual organs are manifest to the naked eye, but if we would follow the process of fertilization in its more subtle details, we need the assistance of the microscope equally as much as with the Cryptogams.

The Flowering plants, to the casual observer, seem to be very distinctly marked off from the Cryptogams; the two great divisions of plant-forms, although they may appear side by side, may outwardly betray no inter-relations, and seem to be of quite independent origin. However, as knowledge resulting from careful research increases, the apparent sharp distinction between the divisions becomes less clearly defined; in brief, our present knowledge amounts practically to

demonstration that the Phanerogams have evolved from heterosporous Cryptogams, and even the latter, in their turn, may have evolved from homosporous forms. In point of fact, heterospory originating in cryptogamic forms, is carried to its logical culmination in the Flowering plants. That this is so will appear from the facts which we shall now adduce.

Flowering plants are also characterized as Spermaphytes, or seed-producing plants. A fertile seed is resultant upon a sexual act which is fundamentally the same as that occuring in all sexual plants. The embryonic plant is in the seed, which is virtually a resting-stage in which adverse conditions can be tided over, and by means of which the species can be propagated in a suitable environment. We must not conclude that because we have to do with "seeds" in Flowering plants, we have ceased to do with spores. The pollen grains of Phanerogams are the equivalents of the microspores in the Cryptogams; the ovules from which seeds develop correspond to the megasporangia of the Pteridophytes, and the embryo-sac, in the ovule, is, practically, the megaspore. Even a prothallus, although much reduced, is traceable in the development of the megaspore within the ovule; and in certain Phanerogams, the Cycads and Cone-bearers, a rudimentary prothallus is formed in the germination of the pollen grain. Thus there is an alternation of generations in the Flowering plants, although it is not so apparent as in the Archegoniates. In the former the sexual generation is highly specialized and greatly reduced, and it is the asexual generation, the sporophyte, which is most palpably the "plant."

In order to make these matters clear we shall consult some illustrations. Fig. 57 represents a flower of the common Wallflower—*a*, is the flower stalk, or pedicel; *c* is the calyx, composed of four narrow leaves, or sepals; the sepals may be green in some varieties, but in most they are tinged with purple; *p* is the corolla, composed of a whorl of four conspicuously coloured broad leaves, or petals. Be it specially noted that both sepals and petals are *leaves*, which have become specia-

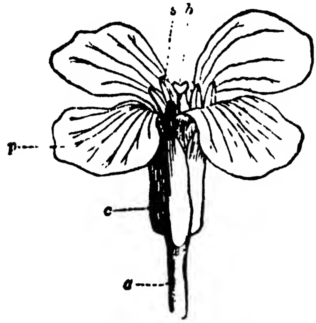


FIG. 57.—WALLFLOWER.
a, Pedicel; *c*, calyx; *p*, corolla; *s*, stamens; *b*, stigma.

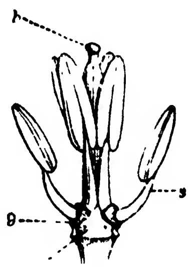


FIG. 58.—WALLFLOWER, WITH COROLLA AND CALYX REMOVED.
r, Receptacle; *g*, honey-glands; *s*, stamens; *b*, stigma at apex of pistil.

lized in form and colour in adaptation to their functions. The calyx and corolla form a floral envelope or perianth, and one purpose they fulfil is the protection of the delicate sexual organs they enclose. The sexual parts of the flower include six stamens, *s* (male), and the pistil (female), which also are specialized leaves, but so greatly modified that their foliar nature is not nearly so apparent as is the case with the sepals and petals. Removing calyx and corolla we see the sexual parts to

greater advantage. In Fig. 58, *s* points to the stamens, the stalk of each being known as the "filament," which bears at its top a two-lobed anther; it is within the anther that the pollen grains are formed. In the same figure *b* points to the stigma, which is borne on the style of the pistil; the style, in our subject, is very short. It connects the forked stigma with the ovary, wherein the ovules are formed. If we dissect an ovary, we find that it is in two compartments, divided lengthwise by a septum. This dividing membrane marks the limits of two special floral leaves from which the pistil is formed; they are called "carpels" (Gr. *karpos*, fruit). Honey-glands, or nectaries (Fig. 58, *g*), occur at the bases of the shorter stamens. The Wallflower is dependent to a large extent upon the visits of insects in the business of pollination. Insects are attracted to its service by the flaring advertisement of the showy petals; the nectar, which acts as a special lure; and also probably by the pleasant scent of the flower. Pollen grains must be lodged on the stigma of the pistil, and it seems desirable that the pollen formed by one flower should reach the stigma of a different flower. This involves cross-fertilization, which is thought to be a benefit to the species. A bee visiting a flower thrusts its proboscis down to the nectaries, and in doing so gets its head dusted with pollen; when it transfers its attentions to another flower it carries pollen to it, and some of it is sure to come in contact with the stigma. The stigma, when ripe, secretes a somewhat sticky fluid, in which sugar is present. This fluid serves two purposes—it causes the pollen to adhere to the stigma, and also enables the grains to germinate. All Flowering plants

Plate IX.

GREATER SPEARWORT (*Ranunculus Lingua*).
Order *RANUNCULACEÆ*.

1. Petal   2. Fruit

do not invite insects to do the work of pollination. There are other pollinating agencies, as we shall see later.

On germination, a pollen grain protrudes a pollen tube, which forces its way between the cells of the stigma, penetrates into the tissue of the style, and ultimately reaches the ovary and one of the ovules contained therein. The pollen tube enters the ovule through an opening known as the "micropyle," and serves as a passage for the fertilizing male element, which, in the end, fuses with the egg-cell, or ovum, in the embryo-sac, such fusion being the real act of fertilization. After fertilization, the egg-cell develops into an embryo, and the ovule containing the latter becomes a fertile seed. The pistil, which encloses the ovules, becomes the fruit. We have said that the pollen grain corresponds to the microspore of the heterosporous Cryptogams; it is necessary to add that on germination it produces the equivalent of an antheridium, in which the male element, corresponding to a spermatozoid, is formed. The germination of pollen grains may be induced by placing them in a watch-glass containing a weak solution of cane-sugar; the glass should be covered by another and kept in a warm place. This is a good method for the student to adopt if he wishes to watch the development of pollen tubes and their contents. Of course, the process cannot be followed without the use of the microscope.

We now turn to the longitudinal section through an ovule and part of the ovary wall of a Wallflower, in Fig. 59, where *p.t.* is a pollen tube that has entered the ovule through the passage of the micropyle, *m*; the

embryo-sac, *e*, *e*, is the megaspore which remains enclosed in the ovule (the megasporangium). Some smaller cells occur in the embryo-sac; of these, three, known as "antipodal cells," represent the prothallus; they are found farthest from the micropyle. Three other cells at the micropyle end are the egg-apparatus, one of them being the ovum, or egg-cell. This is the cell which becomes fecundated by the male element, and

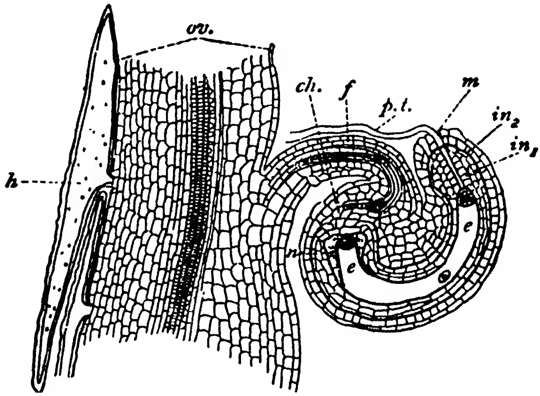


FIG. 59.—WALLFLOWER. LONGITUDINAL SECTION THROUGH AN OVULE AND PART OF THE OVARY WALL. (AFTER D. H. SCOTT.) × 50.

h, A hair; ov, ovary wall; f, funicle of ovule; ch, chalaza; n, nucellus; in_1, inner integument; in_2, outer integument; m, micropyle; e, e, embryo-sac; $p.t.$, pollen tube.

ultimately develops into an embryo. In the Wallflower several embryo-sacs occur in the same ovule; it is unusual for them to be so numerous; in most plants only one is found.

In outlining the story of *Selaginella* (p. 166), we noted that the megaspore, during the early stages of germination, remains in the sporangium, and while there it is nourished by the sporophyte; ultimately, however, it is

SCOTCH PINES (*Pinus sylvestris*), Order *CONIFERÆ.*

discharged, and the egg-cell is fertilized by a ciliated spermatozoid, the operation taking place apart from the sporophyte. In other words, the sexual generation begins to develop in attachment to the asexual plant, but its development is completed apart from it. This peculiar feature of the cryptogamic *Selaginella* is of paramount interest, for it indicates a tendency, and even a start, towards that which is a marked characteristic of all Phanerogamic, or Flowering, plants. In the latter the megaspore (embryo-sac) remains permanently within the megasporangium (ovule); it germinates, and, moreover, the ovum is fertilized while in that position: even at this advanced stage the sexual generation is still dependent upon the asexual sporophyte, and the dependence actually continues until the seed, containing the embryo-sporophyte and reserve food, is fully ripened. Thus, in the seeds of Phanerogams we find embryo-plants which have been formed and capitalized with a reserve before being discharged by the parent sporophyte. This is a magnificent provision for posterity fraught with great economy; less is left to chance than in lower plants, and there is a marked reduction of waste. It is in the Phanerogams, too, that we have the greatest specialization and economy in relation to the development of the microspore (pollen grain). The pollen tube enters the ovule, reaching it with unerring precision, and constitutes a covered way for the passage of the fertilizing male element. There is no waste in the production of male elements; instead of giving a roving commission to a great number of freed spermatozoids, the majority of which are wasted, the Phanerogams have learned the better way of the pollen tube,

through which two generative cells (male elements) pass without losing their way, and one of them fertilizes the ovum. It is the superior machinery of the Phanerogams that enables them to economize, and we need not wonder that a division of plants so ingeniously equipped is now dominant in the vegetable realm.

The critical reader, while admitting the importance of the facts just adduced in their bearing upon the evolution of Flowering plants, may argue that it is a far cry from the sexual generation of a Fern to that of a Wallflower, or from a free, ciliated spermatozoid to the enclosed generative cell; he will ask for "missing links" which indicate transitional phases between the great extremes. Without venturing upon an elaborate discussion, one such missing link of special interest may be mentioned—a link which decidedly connects the Pteridophytes and the Seed-producing plants. This link is found among the Cycads, which resemble Palms and Tree-Ferns in general appearance, but are marked off from them in important particulars: the point of moment to us just now is that in all the Cycads so far investigated the pollen grain on germination forms a pollen tube from which two *swimming spermatozoids* are discharged; these motile male elements actually swim in a watery fluid contained in a cavity of the ovule, in their effort to reach the archegonium and effect fertilization.

The Cycads are the lowest of the seed-bearing plants; they are not numerous now, less than eighty species being in existence, but in the geological Middle Ages they were very abundant, as the fossil remains of extinct species show. The existing species are confined to the warmer regions of the world; some of them form a

marked feature of the vegetation of Central America and Australia.

From what has already been stated we are now in a position to define the Phanerogamia, or Flowering plants, as forms of plant-life in which the asexual generation, or sporophyte, is cormophytic (Gr. *kormos*, the lopped trunk of a tree)—*i.e.*, it has a definite axis of growth; it assumes various forms and produces two kinds of spores—the male pollen grain (microspore) and the female embryo-sac (megaspore). The alternation of generations, so prominent in the Archegoniates, is obscured in the Phanerogamia by seed-formation. The megaspore remains in the sporangium (ovule) throughout its development, and the ovule ripens into a seed. The pollen grain (microspore) produces a pollen tube, and a single cell, which divides into two generative cells (male elements), represents the antheridium. In the Cycads, the lowest plants of the division, the generative cells become swimming spermatozoids.

The Phanerogamia are subdivided into the GYMNOSPERMS and the ANGIOSPERMS, and there is a distinct difference between the two subdivisions. In the Gymnosperms (Gr. *gymnos*, naked; *sperma*, seed) the ovules are not enclosed in an ovary, but occur naked, or exposed, on a scale, or open carpel; they receive the pollen direct into the micropyle. The Angiosperms (Gr. *angeion*, a case) have their ovules enclosed in an ovary formed of coherent carpels, or of one carpel with its margins coherent; the pollen is received on a stigma, which does not occur in the Gymnosperms. The Angiosperms, now so prevalent and so numerous in species, are, according

to geological evidence, pre-eminently modern; the Gymnosperms are more primitive in every respect. Angiosperms are, *par excellence,* "flowering" plants.

There are three classes of Gymnosperms, the Cycads, to which we have already alluded, the Coniferæ, and the Gnetales. We dismiss the last-named with a mere mention, as they are hardly known to any but expert botanists. Concerning the Cycads it should be added that the sexes are represented on separate plants. The so-called "Sago-Palm," *Cycas revoluta,* so frequently cultivated in hothouses, is likely to be the most familiar example; it is a native of Asia. The leaves are rolled up in crozier fashion when young, in which respect they resemble those of Ferns. The megasporangia (ovules) are as large as plums. They are borne on leaves very like ordinary foliage leaves. The male plant produces a terminal cone composed of specialized leaves arranged spirally on the axis, and the microsporangia are produced on the backs of these leaves, in great numbers. The Coniferæ deserve more than a passing mention.

The Cone-bearing plants, the CONIFERS, are conspicuous trees or shrubs with woody, much-branched stems. The Class embraces the well-known Pines, Firs, Larches, Cypresses, Junipers, and Yews. They commonly bear needle-like linear, undivided leaves of firm texture which generally endure through several seasons, so that the plants are said to be "evergreen." They abound in temperate regions of the globe and approach the polar areas; when they are found in the tropics, it is usual for them to occur at mountainous elevations. The sexes are represented in separate flowers and some-

times on separate plants. The flowers, in the majority of the Conifers, are cones consisting of scales (modified leaves) aggregated on a central axis; the scales of the male flowers bear pollen-sacs (microsporangia), and the ovules (megasporangia) occur naked on the scales of the female flowers. Resin is usually present in abundance in the various parts of the plant.

The Spruce Fir, *Picea excelsa*, frequently used as a Christmas tree, exhibits the typical features of the cone-bearing plants. It has been introduced into Britain, where it is not indigenous. It is a forest tree with a vertical stem, often over 100 feet in height; it occurs at a great elevation on the Alps, and abounds in Northern Europe. The branches reach out horizontally, or with a slight downward slope, from the stem. The leaves are needle-shaped, crowded and arranged spirally. The tree is pyramidal in form, and evergreen. Male and female cones (Fig. 60) are borne on the same tree. As will be seen in *B*, the male cones grow in the axils of the leaves of a shoot, the latter having been formed a year prior to the appearance of these flowers. The cone is shortly stalked, and its lower part is composed of small, bright-green vegetative leaves, termed "bracteoles"; the stamens are arranged spirally on the axis above the bracteoles. They are leaf-like, bright-red, and each bears two pollen sacs on its under surface. The female cones (Fig. 60, *A*) are borne at the ends of twigs, when they open their colour is red, and they are between 1 and 2 inches long; at that time they are erect, but at a later stage they hang downwards, evidently with a view to the easier liberation of the seeds, after which they fall to pieces. In a female cone

numerous scales are arranged spirally round the axis; these conspicuous scales are outgrowths from the upper surfaces of smaller, carpellary scales, which precede them in appearance. The larger scales are called *ovuliferous*, because they bear naked ovules as shown in Fig. 60, *C*.

The male flowers produce a vast quantity of pollen, which is very light and easily carried by the gentlest

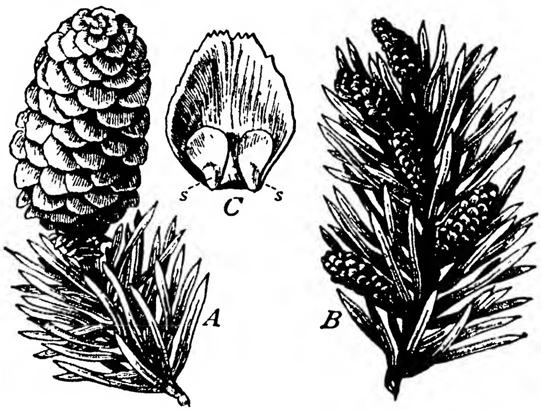


FIG. 60.—SPRUCE FIR (PICEA EXCELSA).
A, Twig with female cone; *B*, twig with male cones; *C*, scale detached from female cone (*A*) bearing two winged ovules (*s*, *s*).

breeze of wind. As the Firs are entirely dependent upon wind for transportation of pollen, they must needs produce pollen in quantity in order that some of it may chance to drift to the female flowers. The pollen of the Firs is exceedingly light in proportion to its surface, and each grain is laterally expanded, the expansions being comparable with wings. It is in the month of May that pollination takes place, and in order that the pollen may reach the ovules with greater

facility, just prior to the time of pollination the female cone elongates and causes the ovuliferous scales to move wider apart, thus allowing space sufficient for the access of the pollen grains to the ovules. At the time of pollination the ovules are not ripe for fertilization, and it is about six weeks before that event takes place. The pollen grain falls on to the micropyle of the ovule, where it germinates; in germination a pollen tube is produced, and by the time it reaches the embryo-sac the ovule is ready for fertilization. The seeds are ripe by autumn, but are not liberated until the following spring, when the scales of the cone open to set them free. The novice will perhaps be glad to have it pointed out to him that the cones which he sees on the trees in winter, or picks up from the ground, are seed-bearers, the ripened results of the female flowers; the male cones, or flowers, disappear when their work of pollen production is fully completed. The seeds, when mature, retain the scales (Fig. 60, *C*) to which they were attached in their ovule stage; these scales are broad and light, they present a good surface to the air, and enable the seeds to be scattered by wind. The movements of the scales of the female cones at various stages are decidedly interesting. As we have seen, they are moved apart to admit pollen to the ovules; after pollination they close up, and thus protect the ripening seeds. Although seeds are ripe in autumn, the scales still embrace them, as it were, and protect them during the hard times of winter; and it is only in the spring, when germination can be promoted by congenial conditions, that the scales relax their embrace and set their precious charges free.

It is worth while to examine the more minute details of the ovule. In Fig. 61 we have a drawing of a longitudinal section of an ovule of *Picea* at the time of fertilization. The letter *p* points to pollen grains lodged at the micropyle; note the pollen tubes, *t*, which

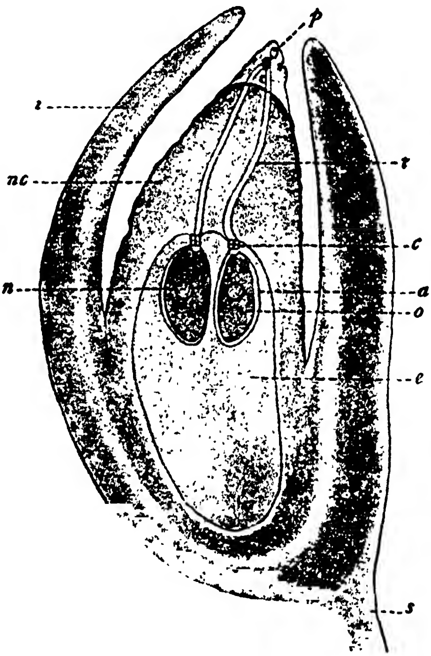


FIG. 61.—PICEA EXCELSA. LONGITUDINAL SECTION OF OVULE AT TIME OF FERTILIZATION. × 9.

i, Integument; *nc*, nucellus; *s*, part of wing; *p*, pollen-grains; *t*, pollen-tubes; *c*, neck of archegonium; *a*, venter; *o*, ovum, *n*, nucleus of ovum; *e*, prothallus.

have penetrated to the neck, *c*, of the archegonium. At this stage of development the embryo-sac is filled with tissue which is formed prior to fertilization; the tissue is the prothallus, *e*, corresponding to the same

PLATE XI.

SCOTCH PINE (*Pinus sylvestris*).

Male Inflorescence above, Female below.

tissue in the Pteridophytes, but much modified and reduced. Here, then, within the ovule of *Picea*, we have a genuine prothallus filling the embryo-sac (megaspore) and supporting archegonia. Each archegonium has a neck of small cells, and a large basal cell called the *venter*, *a*; the venter encloses the egg-cell, or ovum, *o*. In these details we detect a marked similarity to the structures arising in the megaspores of the higher Cryptogams—a similarity so pronounced as to suggest a cryptogamic origin for the Gymnosperms.

It has been pointed out that a rudimentary prothallus appears in the germinating pollen grain of the Gymnosperms (see p. 172); this is awanting in the Angiosperms. In the latter we have reduction and specialization carried to their culmination, but in the former the pollen grain (microspore) is more complicated.

The time elapsing between pollination and fertilization in the Conifers is often greatly protracted; in *Picea excelsa*, as already noted, it is about six weeks; in the Scotch Fir, *Pinus sylvestris* (Plate X.), the seeds take two years to ripen.

The Coniferæ are grouped in two families, the grouping being based on different points of floral structure. First we have the *Taxaceæ*, of which the well-known Common Yew, *Taxus baccata*, the only species found in Britain, is a good representative; it is dispersed over Europe, North and Central Asia, and North America. The entire family comprises only about seventy species. The Taxaceæ usually have female cones with but few scales. The Common Yew is evergreen. Its leaves are from ½ to ¾ inch long; they are narrow and flat. The sexes are represented on different plants. The

flowers grow on the lower surface of the twigs in the axils of leaves formed a year prior to their appearance. The male flowers have scales at their bases, and each flower produces about ten stamens; the number of pollen-sacs borne by a single stamen varies from five to nine. The female flower of the Yew is reduced to a solitary ovule. After fertilization, and during the ripening of the seed, the latter becomes invested in a fleshy cup; this cup becomes red in colour when the seed is mature. It is edible, but the seed itself is poisonous. Birds eat the fleshy investment with avidity, but reject the poisonous seeds, which they assist in dispersing. The Yew is an undoubted Conifer both in respect of its flowers and its foliage, but its fruit is not a cone, in which regard it differs from such cone-bearers as the Spruce Fir or the Larch.

The *Pinaceæ* are the second family of Conifers; they include all the more important species of the class. There are two subfamilies, the *Cupressineæ* and the *Abietineæ*. In the former the leaves are arranged on the branches either opposite to each other or in whorls, and the ovules are erect. In the latter the leaves are arranged alternately, and the ovules are generally inverted. The Cupressineæ are represented in Britain by one genus with but one species, *Juniperus communis*, the Common Juniper. This is a much branched evergreen shrub ranging from 2 to 20 feet in height. The leaves are in whorls of three; they are linear, of spreading habit, about ½ inch long, and terminate in a prickly point. A prostrate, dwarf variety with less prickly leaves occurs on mountainous heights; it is named *Juniperus nana*, but is not entitled to specific rank, as

it is obviously only an adaptation of *J. communis* to hard mountain conditions. In *Juniperus* the sexes occur on separate plants; the male flowers occur in the leaf axils; they are not more than about a line ($\frac{1}{12}$ inch) in length. Small scale-leaves are at the base of each flower, and above them are whorls of stamens consisting of scalelike leaves, each bearing from two to four pollen-sacs beneath. The female flowers also grow in the leaf axils; they consist of scale-leaves at the base, succeeded by a whorl of three to six fleshy carpels bearing as many upright ovules. After fertilization the carpels become succulent and cohere above the seeds, which they enclose. The fruit is two years in ripening, and when ripe, presents the appearance of a blue-black berry with a scar, indicating the union of the carpels, at its tip. Oil of Juniper, used in medicine, is extracted from this plant.

The Cupressineæ include about ninety species, some of which are cultivated for ornamental purposes. Among these are the Arbor-Vitæ (*Thuja*), the Cypress (*Cupressus sempervirens*), found in the Mediterranean region, the Deciduous Cypress (*Taxodium distichum*) famed for the kneelike roots produced above ground, and the Japanese Umbrella Pine (*Sciadopithys verticillata*). *Taxodium mexicanum* grows in the Mexican highlands, often attaining great size. Humboldt estimated that a magnificent specimen, known as the giant tree of Tule, was about 4,000 years old; its proportions may be imagined from the fact that at a height of 130 feet it was found to be about 120 feet in circumference. Other giant trees belonging to this subfamily are the Sequoias of North America, one of which, *Sequoia gigantea*, is com-

monly called the "Californian Mammoth Tree," or Wellingtonia; another is the Red-wood, *S. sempervirens*.

In the broad grouping which we have adopted the Abietineæ include the Araucarias, Pines, Cedars, Larches, and Firs; but some botanists separate the Araucarias into a distinct group—the Araucariaceæ, with two genera, *Araucaria* and *Agathis*. The fourteen species of the group, well represented by the much-cultivated Monkey-Puzzle, or Chili Pine, *Araucaria imbricata*, occur in the Southern Hemisphere; they are cone-bearers, the cones being formed of scales in a spiral arrangement. In the female cones a single ovule occurs at the base of each scale. In the Abietineæ proper there are two distinguishing features: first, the spiral arrangement of the leaves; second, the division of the carpels into cover scales and ovuliferous scales, the latter bearing two ovules on the upper surface. *Picea excelsa*, already described (p. 181), is a fair example of the subfamily. The leaves are all needle-like, but are variously arranged in the different genera. The Firs are divided into two genera, both of which are characterized by producing only long shoots with spirally arranged evergreen leaves, as in *Picea excelsa*. In the genus *Picea*, the bark of the tree is reddish, and the leaves, seen in transverse section, are quadrangular; the cones hang downwards and the scales persist on the cones until, and even after, the seeds are liberated; but in the second genus, *Abies*, represented by the Silver Fir, *Abies pectinata*, a native of the mountains of South and Middle Europe, and cultivated in Britain, the bark is greyish, the leaves are flat, yet needle-like, and marked with two white lines beneath. The cones sit erect, and as in that posi-

tion the cone-scales would hinder seed distribution were they to persist as in *Picea*, when the seeds are ready they fall away to allow the seeds to be scattered without let or hindrance. The remaining genera of the Abietineæ, *Pinus*, *Cedrus*, *Larix*, produce long and short shoots. In *Larix*, represented by the Larch (*Larix europœa*), the long shoots produce linear leaves on all sides and continue the branching; the tree is not evergreen, for the leaves fall off each year, and the short shoots arise as tufts of thirty to forty linear leaves in the axils of the leaves of the long shoots of the previous year. The cone-scales persist after the seeds have been liberated. In the Cedars (*Cedrus*) both long and short shoots bear evergreen leaves, but the cone-scales fall away to admit of distribution of the seeds. There are but three species in this genus, the Cedar of Lebanon (*C. Libani*), found in Asia Minor, the Atlas Cedar (*C. atlantica*), and the Deodar (*C. Deodara*), which occurs in the Himalayas; all three are cultivated as ornamental trees. In the true Pines (*Pinus*) the leaves of the long shoots are reduced to inconspicuous scales, while the short shoots, arising in the axils of these scales, produce tufts of from two to five evergreen leaves. The scales of the cones are decidedly woody, and persist until after the seeds have been liberated. The Scotch Pine (Plates X. and XI.), erroneously called a "Fir," with the botanical name of *Pinus sylvestris*, is a good example of the genus. In the seedlings of this tree the long shoots bear needle-shaped leaves, but after a year or two's growth those leaves give place to the scales which are characteristic of the genus. The fact that green leaves occur on the long shoots of seedlings indicates quite clearly that the

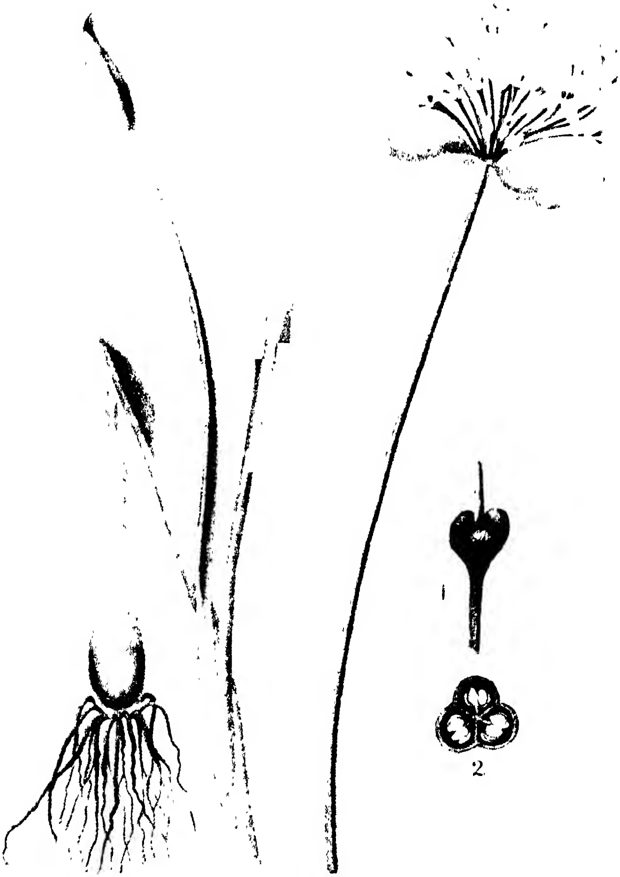
scales of older trees are reduced leaves. The Scotch Pine bears its evergreen leaves in tufts of two, and about twenty species of *Pinus* are alike in this respect. Other species are *P. Pinea*, the Stone Pine, *P. montana*, the Mountain Pine (a dwarf species), *P. Larico*, the Corsican Pine, and the Aleppo Pine, *P. halepensis*. Other species of the genus bear tufts of three and of five leaves; among the former, embracing sixteen Oriental and North American kinds, are *P. longifolia*, with needles half a yard long, found in the Himalayas, and *P. Coulteri*, a Californian species which produces very large cones. There are about thirty-five species bearing tufts of five leaves; the North American Weymouth Pine, *P. strobus*, is an example.

The commercial value of the Conifers is enormous. Among them we have timber trees of the greatest importance, and in addition to their value as timber we have to bear in mind other products secured from them which are exceedingly useful to man. Thus Oil of Turpentine and Resin are got from *Pinus sylvestris*, Burgundy Pitch from *Picea excelsa*, Oil of Juniper from *Juniperus communis*, and Canada Balsam from *Abies balsamea*. The Yew has a decided archæological interest in that at one time it furnished wood for bow-staves. When archery was a mode of warfare the Yew was of great importance; consequently it was planted extensively, particularly in churchyards, where, in safe enclosure, its poisonous foliage was out of reach of cattle.

flower, but as a general rule the flowers of the Angiosperms are hermaphrodite, as in the case of the Wallflower, already described—*i.e.*, both sexes are united in one flower, the stamens being the male and the pistil the female. Stamens, pistil, corolla and calyx are usually arranged in whorls, not spirals, on a much abbreviated axis. It is in the Angiosperms, too, that a new feature becomes firmly established; this is the utilization of animals, principally insects, in the business of pollination. The gaily coloured petals are not produced for idle show, in mere vanity; the nectar is not secreted for sweetness' sake, nor is delicate perfume diffused to pleasure the nostrils of man. These devices exist for the allurement of insects, which, in taking the bait and satisfying their lust for sweet things, become unconscious pollinating agents. This relationship between insects and a vast number of flowers has undoubtedly led to great variety of floral structure. In the Angiosperms fertilization affects the carpels forming the pistil; they develop into the "fruit." The effects may also extend beyond the carpels to the calyx, or even to the floral receptacle, as in the case of the Strawberry, in which the receptacle becomes fleshy and is commonly spoken of as the fruit.

We find another contrast between the Gymnosperms and the Angiosperms in the fact that the former are much restricted in habitat and range, whereas the latter have exhibited much elasticity in adaptation to a great variety of conditions. One can hardly discover an environment where Angiosperms are not to be found. If we wander over the tractless desert, we find some species there. They have invaded pond,

PLATE XII.



GARLIC, or RAMSONS (*Allium ursinum*),
ORDER *LILIACEÆ*.

1 Pistil 2 Cross section of ovary

lake, stream, and even the sea; they occur as giant trees and lowly herbs, as epiphytes and climbers, as insect-consumers and degraded parasites; their potentialities seem to be practically limitless.

The Angiosperms occur in two natural classes, the Monocotyledons and Dicotyledons. Although there is similarity of structure in the two classes, there are radical distinctions which make it difficult to define their relationship.

Monocotyledons.

Cotyledons are seed-leaves; they are developed in the embryo while it is still enclosed in the seed, and they are primary—*i.e.*, they are the first to appear when the seed germinates. Fig. 62 is a drawing of a Wallflower seedling in which *c*, *c*, are the cotyledons. The reader will note that they are different from the later leaves. The Wallflower is a Dicotyledon, for it has two seed-leaves. As the term implies, the Monocotyledons produce but one seed-leaf.

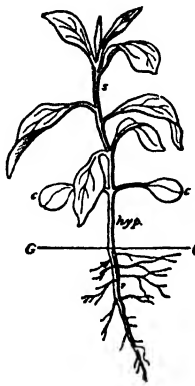


Fig. 62.—Seedling Wallflower. (After Scott.)

c, *c*, Cotyledons; *s*, stem; *G*, *G*, level of ground; *r*, root; *hyp.*, hypocotyledonary stem.

The possession of a single cotyledon is the fundamental distinction of the Monocotyledons; but there are other characters by which they are readily distinguished. Unlike Dicotyledons and Gymnosperms, they have no definite root system due to the development and branching of the main root; as the plant develops the growth of the main root stops, and its function is assumed by

a number of adventitious roots produced from the stem. A transverse section of the stem shows uniformly scattered vascular bundles which develop no cambium, hence annual cambium "rings," by which the age of a plant can be determined, do not appear; in fact, many monocotyledons die down annually, although their underground parts may be perennial. The leaves are usually elliptical, elongated, or linear in shape, and in the great majority of cases their veins are parallel. The flowers betray a marked predilection for the number three; this means that very often their parts are arranged in whorls of three. Thus the perianth may consist of two whorls composed of three sepals and three petals, the stamens may consist of one or two whorls of three, while the pistil is usually formed from a whorl of three carpels united, in which event the ovary is three-celled. Sepals and petals may both be coloured and so much alike as to be indistinguishable.

Monocotyledons are less numerous than Dicotyledons, and, generally speaking, they are simpler in structure; yet we have to remember that within their ranks we have plants, like the Orchids, which are very highly specialized. However, taken as a whole, they may be regarded as being more primitive than the more complicated, varied and numerous dicotyledonous Angiosperms.

It is among aquatic Monocytoledons that we find the simplest forms, but it is difficult to determine whether these are primitive; it is possible that their simplicity is an adaptation to environment; that it may be due to reduction from a more elaborate development —a sort of discarding of useless machinery. Of these

simple flowers the simplest are found in the Naiad Family—the Naiadeæ, in the particular genus *Naias*, composed of submerged aquatic plants represented in all parts of the world; the flowers are unisexual, the male consisting of a single stamen in two cuplike envelopes, or bracts; the female of a single carpel, without a stalk, sitting in the sheathing base of the leaf. The Naiads occur in fresh or brackish water; the leaves, according to species, may be linear, with toothed or entire margins. They are arranged oppositely on the stem. These plants are not common in Britain. The North American species, *Naias flexilis*, has been found in Perthshire, Skye, and Connemara; the Holly-leaved Naiad, *N. marina*, common in tropical and in some temperate regions of the Old World, is recorded as having been found in Hickling Broad, Norfolk.

The Grass Wrack, *Zostera marina*, is common on sand and mud flats near the edge of the sea in temperate regions; it is found at or below low-water mark, even at a depth of 30 or more feet, and is frequently thrown ashore in considerable quantities by the tide. The stem is creeping and roots in the mud or sand; the leaves are grasslike, long, and arranged alternately; they often reach a length of several feet. But although *Zostera* flourishes in the sea, it is not a seaweed—*i.e.*, an Alga—and although its leaves are grasslike, it is not a grass. The simple flowers occur in a flat spike enclosed in the sheath at the base of a foliage leaf; they consist of a few stalkless anthers and three or four carpels. The pollen of this plant is peculiar. It is not found in the form of round grains, but in long thread-like filaments; these are of the same specific gravity as the water

into which they are liberated; hence they do not sink or rise to the surface, nor do they swim—they simply drift in the slightest current, and thus are specially adapted for conveyance by water movement to the stigmas of the female flowers.

Other simple, and perhaps primitive, Monocotyledons of an aquatic habit are the Horned Pondweed, *Zannichellia palustris*, found in ponds or lagoons of fresh, brackish, or salt water; Sea Ruppia, *Ruppia maritima*, accommodated to lagoons, salt marshes, and shallow bays almost the world over, common on the British littoral; and various species of Pondweed, *Potamogeton*, flourishing principally in fresh water. To this list we must add the Reed-Maces, *Typhaceæ*, with two British species, *Typha latifolia*, the Great Reed-Mace, and *T. angustifolia*, the Lesser Reed-Mace, both growing on the margins of ponds and ditches, and the Bur-Reeds, *Sparganium*, with three British species, which flourish on the margins of ponds, lakes, and streams.

The Aroids, or the Araceæ, also exhibit what are probably primitive characters. The best-known British representative is *Arum maculatum*, the Cuckoo-Pint, or Common Arum (Plate XIII.); the Nile or Calla Lily (*Calla palustris*), cultivated in hothouses in Britain, is also well known. In the Cuckoo-Pint the flowers have no perianth; they are borne naked on a fleshy, club-shaped axis called a *spadix*, and the whole inflorescence is protected by a specialized leaf, yellow-green in colour, termed the *spathe*. The club of the spadix is of a livery hue; the female flowers occur in a series at its base, and the male flowers form another series above them. Above the male flowers is a series of barren flowers with hair-

ARUM, or CUCKOO-PINT (*Ar*

ORDER *ARACEÆ*.

like points directed downwards. The significance of this arrangement will be explained when we come to deal with pollination devices, in Chapter X. The specific name, *maculatum*, means " spotted," and it has reference to the brown spots which are usually displayed by the stalked spear-shaped leaves. It is a matter of observation that in some districts these spots are never seen on the leaves. About 900 species of Aroids have been distinguished; the great majority are found in the tropics, but about eighty occur in temperate climes. Some tropical species climb up trees, attaching themselves to the stems by acrial roots; they reach light and air at the tops of the trees and frequently send down long, hanging roots into the moist air of the jungle; sometimes these pendant roots reach the ground and obtain nourishment therefrom.

The Duckweeds (*Lemnaceæ*) show affinities with the Aroids, and are considered by some botanists to be degraded forms of specialized types. Whether they be degraded or no they are eminently successful in the struggle for existence, for they are represented in all latitudes; yet there are only two genera embracing about twenty species. The Lesser Duckweed, *Lemna minor*, is practically ubiquitous in its distribution. All the Duckweeds are floating plants of small size; they usually propagate by budding or by hibernating bulbils; they rarely produce seed. The flowers, when produced, are extremely simple. They rise from a fissure in the upper surface of the green scalelike leaf, or in its edge; they consist of a very small membranous spathe enclosing a single carpel and one or two stamens. Four species of the genus *Lemna* are found in Britain. The

second genus of the order, *Wolffia*, includes twelve species, distributed in Europe, Africa, and America; *W. arrhiza*, the Rootless Duckweed, is found in the south-east of England, where, however, it is not known to flower. The frond of this species is about $\frac{1}{20}$ inch long and half as broad; it is no larger than a grain of sand, and rootless. The flowers burst through the upper surface of the fronds; they are not enclosed in a spathe, as in *Lemna*. They consist of a single stamen and one carpel. *W. arrhiza* is the smallest known flowering plant.

The Alismaceæ are monocotyledons of a somewhat higher type. They are marsh plants found in warm and temperate latitudes. The leaves rise chiefly from the roots, and the inflorescence is frequently much branched. The Flowering Rush, *Butomus umbellatus* (Plate XIV.) is a handsome plant with long erect triangular leaves and a leafless flower stem attaining a height of from 2 to 4 feet. The flowers, which are rose-coloured and very showy, are borne in an umbel; each flower comprises a perianth of six coloured segments, nine stamens, and six carpels. The generic name is from the Greek, *bous*, an ox, and *temno*, to cut, indicating that if cattle attempt to eat the leaves they are liable to get their mouths cut. The Common Arrowhead, *Sagittaria sagittifolia*, has leaves with long stalks, rising from the root, and with blades shaped like an arrowhead; the flowers are unisexual and show some specialization. The male flowers have numerous stamens and also carpels, but the latter are sterile; the female flowers have numerous small carpels in a dense head, and suppressed stamens; so this plant has become unisexual by the respective suppression of carpels and stamens,

FLOWERING RUSH (*Butomus*
Order *ALISMACEÆ*

probably in order that it may be advantaged by cross-pollination. The Water-Plantains (*Alisma*) are also conspicuous members of this group.

But the most important of the Monocotyledons are the Grasses, which are cosmopolitan, and include species of great economic value. They supply food for man and beast. The cereals—wheat, barley, oats, rye, rice, etc.—which are of inestimable value as food for man, are all grasses; the herbivorous ox eats grasses and transforms them into beef; man eats the beef, and in this respect is a vegetarian, and a grass-eater, once removed. Wheat (*Tricitum vulgare*), Rye (*Secale cereale*), Barley (*Hordeum vulgare*), Oats (*Avena sativa*), and Maize (*Zea mais*) are widely cultivated in temperate regions, the latter very largely in America. Rice (*Oryza sativa*) is of the utmost importance in tropical climes, and Millet (*Andropogon Sorghum*) is an extensively cultivated African cereal. The Sugar-Cane (*Saccharum officinarum*) is a perennial grass indigenous in tropical Asia and cultivated, on account of its sugar-yielding sap, throughout the tropics. The tropical Bamboos (genus *Bambusa*) are also grasses, and, as every-one knows, are useful in a hundred-and-one ways; they serve as material for houses, bridges, ladders, water-conducting pipes, and even cooking vessels. Some of these giant grasses attain a height of about 80 feet and a diameter of more than half a yard. Of the *Gramineæ*, or Grasses proper, there are between three and four thousand known species, of which about one hundred and twenty occur in Britain. The family is grouped with the Sedges, *Cyperaceæ*, in the Order *Glumifloræ*, which is defined as including grassy herbs

with sheathing leaves, bearing insignificant flowers without coloured perianths and pollinated by wind agency.

The Gramineæ, or Grasses, include annual and perennial species. The latter possess creeping rhizomes—*i.e.*, underground stems of rootlike appearance. The majority of the perennials produce new stems and leaves each season, and these die down at the season's end. The stem of a grass is cylindrical, and, with the exception of Maize and Sugar-Cane, hollow, with solid, swollen joints or nodes; the leaves have a basal portion which sheathes the stem, and an unsegmented, parallel-veined, linear blade. A small scale, the ligule, sometimes taking the form of hairs, is situated at the junction of the blade and the sheath. The small flowers are arrayed in spikelets, which, in their turn, enter into the composition of inflorescences of various kinds, according to species. It is usual for each spikelet to embrace several flowers. The spikelet has at its base, in most cases, a pair of barren, chaffy bracts (glumes); but in various species these glumes number from one to three or four. Each flower in the spikelet occurs in a sheathing scale, the *palea,* while subtending the flower, and outside the palea is the flowering glume, which is frequently awned—*i.e.*, furnished with a bristle that bears a number of small, stiff hairs directed backwards. There is no true perianth, but in many instances it is replaced by two very small scales, the *lodicules*, found above the palea, between it and the flower proper. In brief, each flower of a spikelet occurs within a palea and a flowering glume, and the spikelet itself is enclosed by protective outer glumes, usually two in number. As to the essen-

PLATE XV

TWAY-BLADE (*Listera ovata*),
ORDER *ORCHIDACEÆ*.

1. Flower, side view
2. Flower, front view
3. Essential organs: stamen with cover turned b.
4. Cross-section of ovary

tials of the flowers, each ovary, containing one ovule, is surmounted by two feathery stigmas, and the stamens, with rare exceptions three in number, consist of long filaments bearing two-celled, pendulous anthers, which hang outside the flower so that their dustlike and abundant pollen may be readily dispersed by wind. The feathery stigmas afford an extended surface for the reception of pollen.

The Cyperaceæ, or Sedges, have leaves resembling those of Grasses, but differing from them by the general absence of a ligule and by the fact that their sheathing bases are closed. In the Grasses the sheath is open; it grips the stem, but it can be unfolded and removed without being torn. But there can be no unfolding of the sheath of a Sedge, for its edges are soldered and the sheath is a tube; therefore, if we tear a leaf away from its stem, the tube is ruptured. The stem of Sedges is usually triangular in transverse section; it is seldom hollow as in Grasses, nor does it generally have swollen joints. The flowers are either unisexual or hermaphrodite (p. 192); they occur in the axils of small glumes, and are arranged in spikelets. As an adaptation to wind-pollination, the anthers and stigmas project from the spikelets. Sedges are numerous, between two and three thousand species being known. They are represented in all climes; about one hundred species are found in Britain. The papyrus of ancient Egypt was prepared from the pith of the flowering stems of the Sedge *Papyrus antiquorum.* This species grows in the region of the Upper Nile, also in Palestine and Syria; it attains a height of about 10 feet, and its stems are found up to 4 inches in diameter.

Higher in the scale of the Monocotyledons we come to the Order Liliifloræ, including the Rushes, which are very grasslike, the Lilies, Daffodils, Irises, Yams, Bryonies, and Pineapple. Then we have the tropical Scitamineæ, including the Banana, *Musa sapientum*, the South African "Traveller's Tree," *Ravenala Madagascariensis*, which has hollows in the sheaths of the leaf-stalks in which water collects, and leaves of great size, also the Ginger plant, *Zingiber officinale*; the "Ginger" in common use is obtained from its rhizomes.

The Monocotyledons are crowned by the remarkable and ingenious Orchids, which may be rightly regarded as the most specialized plants of the whole class. We shall have more to say about them in a later chapter; in the meantime it is sufficient to note that they are numerous, over 5,000 species being known, of which less than fifty occur in Britain.

Dicotyledons.

As in the animal kingdom animal life finds its fullest manifestation in the Mammals, with Man at their head, so it is in the ranks of the Dicotyledons that plant-life is most completely expressed. From geological evidence it plainly appears that Mammals are the last-comers, and it is equally clear, upon similar evidence, that the most advanced Dicotyledons are the latest plants. We are now in the age of Mammals and Dicotyledons; the former are dominant among animals, and the latter are the chief among plants. Whether Dicotyledons of the most advanced type are the "last word" of plant-life, or whether there is yet to be further advance, can be

SWEET-SCENTED ORCHIS (*Habenaria conopsea*),
ORDER *ORCHIDACEÆ*.

determined only in the æons to come. The botanist can to some extent scan the progress of the past, and, in a general way, trace a steady advance, involving untold ages, from a simple Alga to the highly specialized Daisy; but he knows not what the future has in store, nor, as a strict scientist, dare he venture to assume the rôle of prophet.

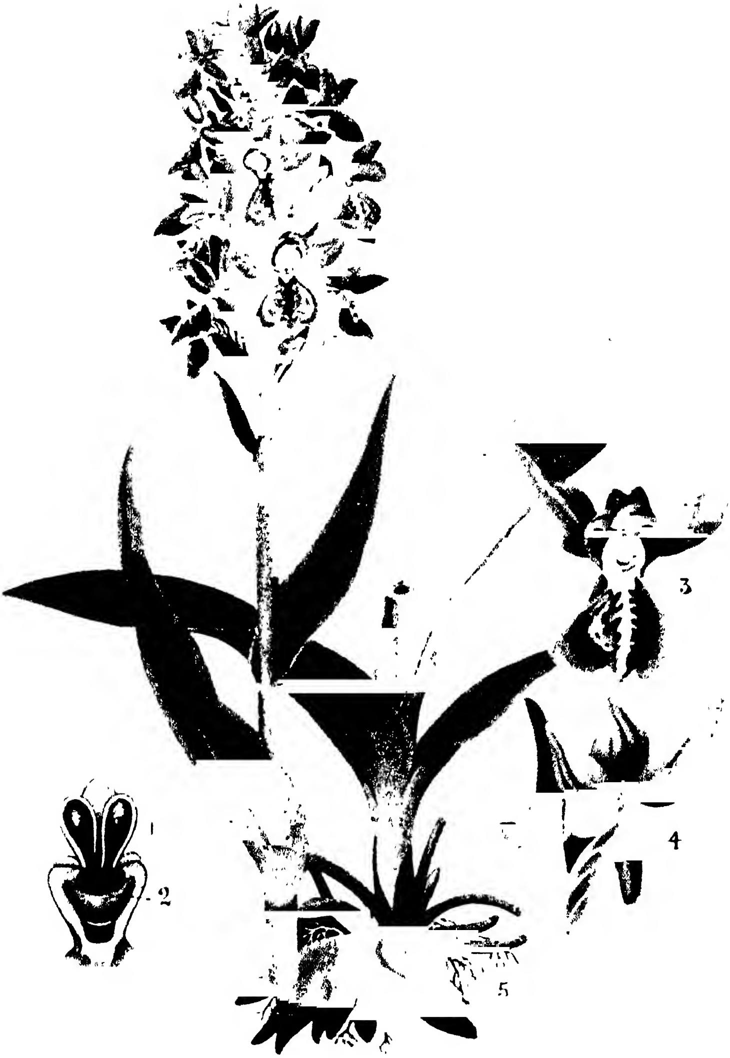
The Dicotyledons have tried their mettle and demonstrated their fitness to exist by their great success in the struggle for existence. As a rule they give a prevailing character to the vegetation of a district. In certain situations, such as those occupied by Grasses, Monocotyledons seem to dominate, and they unquestionably play an important and necessary part in the economy of Nature; but in point of numbers they are fewer than their more successful competitors, which outnumber them by at least four to one. There are somewhere about 20,000 species of Monocotyledons distributed over the world, whereas more than 80,000 species of Dicotyledons have been distinguished. Few Monocotyledons attain the dimensions of trees; but, setting aside the Conifers, which, as we have seen, are Gymnosperms, in all temperate regions the forest trees are all Dicotyledons. Among "weeds," the most successful aggressors, in number of species, are Dicotyledons; with the exception of Grasses, there is barely a Monocotyledonous weed that is of any account. Angiosperms generally have displayed remarkable elasticity in adaptation to environment, but it may be claimed that among them the elasticity of the Dicotyledons is the more pronounced.

The plan of this book, as well as the limitations both

of author and space, preclude the possibility of anything like a full account of these last arrivals in the plant realm, nor do we find it practicable to present the reader with a general survey, even were such desirable. We must content ourselves with a statement of fundamental characters, and an indication of the scale of forms that may be regarded as lower, higher, and highest. This in itself is no easy task, for the Dicotyledons are a mighty assemblage, a natural unit embracing every imaginable, and perhaps unimaginable, variation. In the presence of such a multitude it is difficult to "see wood for trees." The difficulty is accentuated by the fact that it is not easy to determine whether certain characters are really primitive or the results of adaptive simplification.

Dicotyledons are plants with two seed-leaves. This is the most constant character throughout the class, but it should be noted that there are a few exceptions in which only a single cotyledon is present. This phenomenon, however, seems to be usually due to the suppression or abortion of the second cotyledon. We may, perhaps, yet discover some plants which display both monocotyledonous and dicotyledonous characters, and so may be certainly regarded as links between the two great classes. Such would be distinctly interesting, as their relations, according to present knowledge, are decidedly vague.

The typical flower of the Dicotyledons has its parts arranged in whorls of four or five. In the seed the two cotyledons enclose the embryo (the *plumule*), and on germination the plumule sends a root, known in its early stages as a *radicle*, down into the soil, and a stem into



MARSH ORCHIS (*Orchis latifo*

ORDER *Or*

1. Pollinia
2. Stigma
3. Flower, enlarged
4. Flower, showing twisted ovary
5. Root, new tuber on left

the light and air. The stem normally has bark on the outside. Within the bark, reading from circumference to centre, there are woody fibre, spiral vessels, cellular tissue, and the central pith. The stem grows in diameter by deposits formed between the fibre and the bark; hence Dicotyledons are also described as *Exogens* (Gr. *exō*, outside; *gen*, root of *gignesthai*, to be produced). It is owing to this mode of growth that the shrubs and trees of this class have their wood arrayed in " annual rings," or concentric layers. Contrasted with the leaves of the Monocotyledons, which are usually parallel-veined and more or less linear, those of the Dicotyledons are reticulate in venation (*i.e.*, their veins form a network), and also much varied in form. As a further contrast between the two classes, it is observed that in Dicotyledons the radicle put forth by the embryo persists, and usually develops into a tap-root giving rise to a branched root-system. This is not so in Monocotyledons (see p. 193). The great diversity of floral form leads on to much variety of fruit and seed, and the inflorescence (the arrangement of the flowers on the stem) is also greatly varied.

At this juncture it will be advisable to consider some forms of inflorescence. When the flowers spring from the angle between steam and leaf the inflorescence is said to be *axillary;* the Speedwells are an example. When the flower stalk springs direct from the root and bears no leaves, it is called a *scape* (Primrose). A *spike* is a flower-stalk bearing a number of sessile (stalkless) flowers; example, Verbena (Fig. 63). A *raceme* has flowers arranged as in a spike, but each flower has a simple stalk; example, Currant (Fig. 64). In a *corymb*

(Fig. 65) we have a raceme with stalks getting shorter as they approach the apex of the flowering stem, as a result of which the flowers are brought almost to a level. An *umbel* consists of flowers with stalks all rising from a common point (Ivy). A *compound umbel* occurs when each stalk arising from a common centre bears another umbel instead of a single flower; example, Carrot (Fig. 66). A *cymose* inflorescence has the

Fig. 63.—Spike of Verbena.

Fig. 64.—Raceme of Currant.

Fig. 65.—Corymbose Inflorescence.

flowers almost on a level, but on irregularly branched stalks (Elder). A *catkin* is a crowded spike of flowers of one sex; each tiny flower is protected by a scalelike bract instead of an ordinary perianth (Hazel, Fig. 67). Neither the compound umbel nor the catkin is found among the Monocotyledons.

The Dicotyledons are divided into two groups, the *Choripetalæ* and the *Sympetalæ*. In the former the

perianth segments are always free (Gr. *choris*, free; *petalon*, a petal)—*i.e.*, they are never fused together; but in the Sympetalæ (Gr. *syn*, together, and *petalon*) a corolla is always present, as well as a whorl of sepals, and the petals are invariably united or coherent. Sometimes the sepals are also joined.

In attempting to decide which of the Dicotyledons

FIG. 66.—COMPOUND UMBEL OF CARROT.

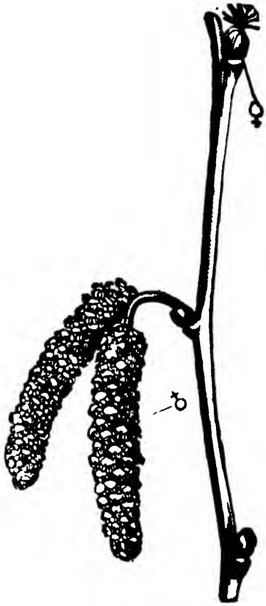


FIG. 67.—HAZEL.
♂, Male catkins; ♀, female catkin.

are lower or higher, as the case may be, it is necessary to understand the principles upon which such a decision rests. The fundamental principle must needs be specialization. We have already appreciated the fact that all the organs of a flower are modified leaves: the sepal is a

leaf, the petal is a leaf; stamens and carpels are also leaves, and because they bear spores they are correctly described as spore-bearing leaves—sporophylls. We naturally conclude that plants possessing such highly modified leaves are much farther advanced than plants which do not possess them. And these modifications involve specialization in function. The cone-scales of the seed-bearing Pine are modified leaves, and the Pine is an undoubted advance upon a Club-Moss. A gaily coloured perianth may usually be regarded as an advance upon the monotonous green. Cohesion of parts is certainly an indication of specialization. If we detect progress from a lower to a higher form in the modification of green leaves into highly coloured petals, we must note further progress when petals are united, or coherent, or, in other words, when the corolla is a unit composed of organically coherent petals. This being so, we have no hesitation in concluding that the Sympetalæ are as a whole more advanced than the Choripetalæ, because the latter have free perianth leaves, while the former have coherent petals. The modification of a leaf into a carpel is evidence of advance, and specialization in the carpels marks a higher development. A Buttercup bears flowers in which all the parts are separate or free; its carpels are clustered together, but not fused. It is, therefore, less highly specialized than the Primrose, which is sympetalous, and has its carpels fused into a compound pistil. Indeed, we may take it for granted that in floral evolution the passage from lower to higher types has involved reduction in the number of free parts—a reduction due to their cohesion. Bilabiate flowers, such as the Toadflax, Snapdragon,

PLATE XVIII.

SWEET CICELY (*Myrrhis odorata*), ORDER *UMBELLIFERÆ*.

PLATE XIX.

HEDGE CONVOLVULUS, OR BINDWEED (*Calystegia sepium*), ORDER *CONVOLVULACEÆ.*

Foxglove, and Yellow-Rattle, which have highly specialized corollas and a reduced number of stamens, are more advanced than the Tubifloræ, which have regular, sympetalous, tubular, or funnel-shaped corollas; the Bindweed (Plate XIX.) and the Henbane (Plate XX.) are examples. There are many points that have to be taken into account before we can definitely decide upon the exact position in which we may place a plant in the evolutionary scale; and in formulating a decision we have to bear in mind not only the points above mentioned, but the fact that apparent simplicity may be due to specialization; also that there is degradation as well as advance, both in the animal and plant kingdoms.

We have decided that the Sympetalæ, with their united petals, are higher than the Choripetalæ, which have free petals. But in each great division there are grades of development; indeed, we may liken the whole plant realm, or any great division of it, to the human race. There are peoples which are in the van of progress, they are versatile and equipped for the exigencies of competition; other peoples are less pushful, and quite content to benefit by progress without making it. Some men think in terms of the twentieth century; others are medieval in outlook. Some are at the heart of civilization, others are at its fringe or beyond its borders. Some tribes are confirmed degenerates; others show a disposition to progress. There are the highly cultured, the less cultured, and the barely cultured. It is a far cry from the civilization of the remote Highlands to that discoverable in the Metropolis, and, although the distance is shorter, the gulf is no less pronounced between Whitechapel and Park Lane. Humanity in the aggre-

gate is a unit composed of heterogeneous parts, and so is the plant kingdom. Ancient and modern, simple and complex, lower and higher, regenerate and degenerate, are all parts of the great whole. They occur side by side, but their very proximity, to the trained eye, serves to show their distinctions. In both the Choripetalæ and the Sympetalæ there are plants that may be termed "lower," "higher," and "highest," and there are also gradationary forms connecting the groups.

The *Amentaceæ*, which usually bear single flowers arranged in catkins, and are generally pollinated by wind, are considered to be the lowest of the Choripetalæ. They are mostly trees or shrubs; the flowers are unisexual, inconspicuous. They are either destitute of a perianth, or in species where it is present it consists of a single whorl, is never brightly coloured, but always reduced to inconspicuous scales. It is frequently argued that the inflorescence of these catkinate plants is a reduction from a more advanced ancestry; but this need not be admitted, especially as there is some geological evidence in favour of their being primitive among Dicotyledons. The Amentaceæ include the Willows, Poplars, Oaks, Birches, Alder, and Hazels. In the Willows (*Salicinæ*) the sexes are represented on separate plants, the male and female flowers occurring in simple catkins. In Britain the most important species are the Crack Willow (*Salix fragilis*), the Weeping Willow (*S. Babylonica*), the Osier (*S. viminalis*), and the Sallow or Goat Willow (*S. Caprea*). The last-named species is the source of the so-called "palms" gathered by children for Palm Sunday. The "palms" are the catkins, which appear before the leaves. The Sallow is pollinated by

HENBANE

ORDER S

bees and moths. The Poplars are of the Willow Order. They include the Lombardy Poplar (*Populus pyramidalis*), the Black Poplar (*P. nigra*), the White Poplar (*P. alba*), and the Aspen (*P. tremula*). Both Poplars and Willows favour temperate and cold latitudes. The Oaks, as well as the Beeches, belong to the *Cupuliferæ*, in which the sexes occur on the same plant, but not in the same flower. In this Order are the Common Oak (*Quercus Robur*), the Cork Oak (*Q. Suber*), and the Common Beech (*Fagus sylvatica*), the last being a familiar forest tree in Britain. Another species of Beech, *Fagus ferruginea*, is as familiar in North America as *F. sylvatica* is in our own woods. The Cupuliferæ favour temperate regions. *Castanea vesca*, the Edible Chestnut, a native of the Mediterranean region, is of the same Order. It has been introduced into Britain. In the Birch Order (*Betulaceæ*) the sexes appear on the same plant. The Order includes the Common Birch (*Betula alba*), the Hazel (*Corylus avellana*, Fig. 67), the Filbert (*Corylus tubulosa*), which grows in Italy, the Hornbeam *Carpinus betulus*), and the Alder (*Alnus glutinosa*, Fig. 68). The Betulaceæ favour Northern regions. Willows and Birches are among the most

FIG. 68.—ALDER.

1, Branch with male (below) and female catkins; 2, female flower; 3, male flower.

northerly of shrubs and trees. The Walnut (*Juglans regia*), a native of Western Asia, and the Sweet Gale (*Myrica gale*), a low, resinous, fragrant shrub growing on British moors, also belong to the Amentaceæ.

The *Polycarpicæ* (Gr. *polys*, many; *carpos*, a fruit) and the *Centrospermæ* (Gr. *centron*, the centre; *sperma*, a seed) are also probably primitive among the Choripetalæ. The former are distinguished by usually having free carpels, as in the case of the Buttercups (Fig. 69), in which none of the floral parts cohere. The Buttercups belong to the Ranunculus family, in which there are such diverse forms as the Anemones, Larkspurs, and Monkshood. The diversity of form seems to indicate specialization for insect pollination. There is evident advance within the family in this respect, but very little in regard to the disposition of carpels and stamens. In the Centrospermæ the carpels are usually coherent, and the ovary is always one-celled. The name is due to the fact that the ovules (or single ovule) are central in the ovary, and arise from the apex of the floral axis, which forms a *placenta*—the term applied to the portion of the ovary bearing ovules. The lower members of the Order are the Sorrels, Docks, Buckwheat, Spinach, Goosefoots, and Beet. These have inconspicuous flowers, and certainly are not the less vigorous for generally being self-fertilized. Higher in the Order we have the *Caryophyl-*

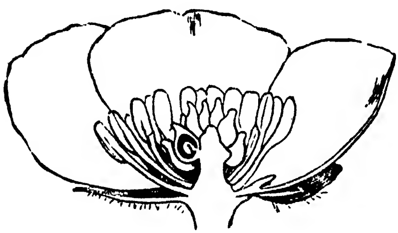


FIG. 69.—SECTION OF FLOWER OF BUTTERCUP (RANUNCULUS).

CORNCOCKLE (*Agrostemma githago*),
ORDER *CARY*

1. Calyx
2. Ovary
3. Ovary section, longitudinal
4. Ovary section, across
5. Pistil
6. Stamen (front)
7. Stamen (from behind)

laceæ, in which there are some conspicuous and even showy flowers. The Pinks, Carnations, Soapworts, Corn-cockle (Plate XXI.), Campions (Plate XXII.), and Stitchworts are examples.

In the Poppies (*Papaveraceæ*), a family including the Poppies proper, genus *Papaver*, and the Greater Celandine (*Chelidonium majus*, Plate XXIII.), and also in the Fumitories (*Fumariaceæ*) and the Cross-flowers (*Cruciferæ*), including the Wallflower, Mustard, Stocks, Cuckoo-flower (Plate XXIV.), and numerous other genera and species, the floral envelopes and stamens are inserted on the floral receptacle, and the carpels cohere to form a compound pistil. In such forms we may trace an advance upon the more primitive Choripetalæ.

We have no hesitation in deciding that the most specialized choripetalous plants are the *Calycifloræ*. Here the sepals cohere, and form a cup-shaped or tubular calyx, with stamens and petals inserted on its margin. This group is very numerous, and in many of the forms the ovary is " inferior "—*i.e.*, the calyx and corolla are united to the top of the ovary, and the latter, of course, is inferior to (that is, *below*) the floral envelopes. The Calycifloræ include the Roses, Saxifrages, Willow Herbs. The Umbellifloræ (Hemlock, Carrot, Parsley, Fennel, Earthnut, Parsnip, etc.), Ivy, Dogwood, and the Pea and Bean tribe.

Taking the cohesion of parts as an indication of specialization and advance, we note that the cohesion of the carpels indicates a first advance, and this is followed in the ascending series by the union of sepals. Further specialization is evident when the petals of the corolla cohere, as is the case in the sympetalous Dico-

tyledons. The Sympetalæ are by no means all on the same level of advance, nor must the reader surmise that they all appeared subsequent to the Choripetalæ. Many of the latter are highly specialized, and doubtless some forms in both great divisions are to be regarded as contemporaneous. The same may be said in respect to Monocotyledons in relation to Dicotyledons. Forms of various kinds may have arisen from different origins, and have attained high specialization, not in succession, but side by side. It would be foolish to think of floral evolution as following a direct line from lower to higher. It should rather be pictured in the form of a family tree. Just because Orchids are Monocotyledons, they are not to be treated as antedating Daisies, which are Dicotyledons. Indeed, Orchids are modern, and there are indications that they are not yet at the climax of their evolution. There may have been a period in which some Choripetalæ existed as the only Dicotyledons, but it is probable that the higher forms of the Division attained their specialization side by side with the Sympetalæ, and that the latter began a successful career upon their own particular lines, so to speak, in early choripetalous times.

There are two divisions of the Sympetalæ. In one the number of petals is equal to that of the carpels—these are the *Isocarpæ* (Gr. *isos*, equal; *carpos*, fruit); in the other the carpels are fewer than the petals—these are the *Anisocarpæ* (Gr. *anisos*, unequal). Separate carpels are never found in the Sympetalæ. They invariably cohere, and form a compound pistil. Following the principle already laid down, we naturally conclude that among the Sympetalæ the Isocarpæ are more primitive

SEA BLADDER-CAMPION (*Silene maritima*),
ORDER *CARY*[illegible]

1. Essential organs 2. Cross section, ovary
3. Fruit open

than the Anisocarpæ, because in the latter reduction of the carpels in number, due to their cohesion, is apparent.

The Isocarpæ include a number of familiar plants belonging to the Orders Ericales, Diospyrales, and Primulales. The Ericales include the Wintergreen (*Pyrola*), the parasitical Fir-Rape (*Monotropa hypopitys*), the members of the Heath family, among which are the Azaleas, Rhododendrons, Andromeda, the various Heaths, the Arbutus (Strawberry-Tree), and the Bear-berries, Cranberries, Huckleberries. The Primulales are represented by the Primroses, Pimpernels, Water Violet, Cyclamen, Loosestrifes (*Lysimachia*), Chickweed Winter-green (*Trientalis Europæa*), Sea-Milkwort (*Glaux maritima*, Plate XXV.), and some systematists include the Plumbaginales, the Thrift (*Armeria*), and Sea-Lavender, (*Statice limonium*) in the same Order. The Diospyrales are not represented in Britain. In this Order are Ebony (*Diospyros ebenum*) and a Japanese fruit tree named *Diospyros Kaki*.

The Isocarpæ are few in comparison with the Aniso-carpæ, in which there are grades of specialization indicating advance on particular lines. Here belong the Tubifloræ, having funnel-shaped flowers, including the Convolvulus, Bindweed (*Calystegia*), the parasitic Dodder, Comfrey (Plate XXVII.), Alkanet (Plate XXVI.), and a number of allied forms. These are less specialized than the Labiatifloræ, with their bilabiate flowers and reduced number of stamens. Among the Labiates are the various species of Mint, the Gipsywort (*Lycopus Europæus*), Thyme, Marjoram, Wood-Sage, Bugle, the Hemp-Nettles (*Galeopsis*), and the Dead-Nettles (*Lamium*).

Of all the vegetable kingdom, according to our present knowledge, and if our interpretation of the facts is correct, the *Aggregatæ* are the most specialized and the highest. These are anisocarpous plants, with flowers aggregated into heads, each flowerhead being surrounded by an involucre of bracts. The stamens are placed on the petals, and the ovary is inferior (p. 213). The less specialized of this highly developed group are the Honeysuckles, the Teazels, and various species of Scabious. The highest development is observed in the Compositæ, including about 10,000 species. Here we have the Daisies, Sunflowers, Asters, Chrysanthemums, Dandelions, Hawkweeds, etc., which are frequently, but rather loosely, referred to as " compound " flowers. In some forms—for example, the Daisy (*Bellis perennis*)—there are two kinds of florets—the " disc " and the " ray." The latter make the flowerhead conspicuous ; in some cases they are sterile. The flowerhead of the common Daisy, although it is commonly spoken of as " a flower," is composed of about 250 individual flowers compacted together. Of these, about fifty are white, straplike " ray " florets, each having a pistil, but no stamens; while about 200 tubular, five-cleft yellow flowers, with stamens and pistil, form the central disc. The lobes of the corolla of the yellow disc-florets indicate that five petals have cohered to form this floral envelope, and doubtless the same number of petals have entered in combination to form the straplike corolla of each ray floret, although here sympetaly is so far advanced that there is little sign of the primitive five petals. Yet careful examination of the base of one of these white florets yields the impression of the floret being a split tube.

GREATER CELANDINE (*Chelidonium majus*),
ORDER *PAPAVERACEÆ*.

CUCKOO-FLOWER (*Cardamine pratensis*),
ORDER *CRUCIFERÆ*.

1. Fruit 2. Stamens 3. Petal

In the florets of the Dandelion there are distinct notches at the tips, indicating that five petals cohere to form the corolla.

The floral head of the Compositæ is, then, a colony of flowers, each one showing sympetaly, a reduction of parts, and high specialization. The principle of cohesion of parts is here extended even to the stamens, which are five in number, and usually joined by their cuticles in such a manner as to form a tube. The anthers open into the tube, shed their pollen therein, and this vital dust is swept out of the tube and placed in a position in which it can be picked up by insects by means of the style of the pistil. The style acts as a sort of tube brush. It sweeps out the pollen as it extends in length. The calyx in the Compositæ is either reduced to feathered hairs or simple bristles, or entirely suppressed. In many species it ultimately forms the hairy *pappus* which crowns the seed, and enables it to be transported by the wind to "fresh woods and pastures new."

The high specialization of the Compositæ has not been attained in vain, as is evident from the success of the family in the struggle for existence, and the vast number of existing species. They form about a ninth part of all the flowering plants, and are represented in all parts of the world, even in the extreme limits of vegetation towards the Poles. For the most part they are herbs, but there are tropical species which attain the proportions of shrubs and even trees. The reader, however, will have observed that eminence in the scale of life does not consist in magnitude, but is evidenced by specialization and adaptation to high uses. Man is

pigmy beside an elephant, yet he is much further advanced. He can perform greater feats by the exercise of his intelligence than an elephant can manage by brute strength. The humbly proportioned Daisy can succeed where a mammoth Sequoia would be utterly at a loss.

We have now arrived at the end of our rapid review of the gamut of plant-life. We have seen plant-life in its simplest forms, and traced it to its highest expression. To some extent we have observed the stages of progress, but we have not explained the greatest of all phenomena—Life itself. To do so, we should have to enter the realm of metaphysics, and indulge in a discussion which has no rightful place in a volume such as this.

A. SEA-MILKWORT (*Glaux maritima*), ORDER *PRIMULACEÆ*.

1. Flower, enlarged 2. Fruit, enlarged

B. BROOKWEED (*Samolus valerandi*), ORDER *PRIMULACEÆ*.

3. Capsule dehiscing, from above 5. Longitudinal section of ovary
4. Petal

C. BOG PIMPERNEL (*Anagallis tenella*), ORDER *PRIMULACEÆ*.

6. Part of flower, showing hairy stamens 7. Pistil

CHAPTER VIII

FOSSIL PLANTS

Any conclusions we have reached in respect to the gamut of plant forms have, up to the present point, been based upon structural details, but our study could hardly be complete without some reference to the testimony of the rocks. Fossil Botany within recent years has received marked attention at the hands of specialists, and some important discoveries in regard to the plant life of past ages have been made. The study, although it has yielded valuable results, is as yet in its infancy. We may look for further fruits in the years to come.

The fossils that are found in the stratified deposits of the earth's crusts are interesting and valuable records of the life, climate, and conditions of past ages. They help us to decide the geological age of the rocks with which they are associated, and we naturally look to them for unimpeachable evidence as to the sequence of life-forms in the gamut of creation. If there has been evolution of life-forms from the earliest times to the present day, and a gradual development, or even a series of sudden appearances, of more complex forms, there ought to be a succession of fossils indicating the progress of evolution. Not that we must expect too much from fossils, for we know that myriads of plant and animal bodies return "ashes to ashes, and dust to dust,"

leaving not a trace of their existence. As it is now, so has it been throughout the ages. The great majority of life-forms have utterly perished. Such fossils as are found are the casts, impressions, or petrifactions of a minority of bodies that happen to have been deposited in conditions favourable to fossilization. A tree-trunk that falls into a rapid stream and is carried into a lake may rapidly become covered with a deposit of sand. It is more likely to become a fossil than a trunk lying in a moist wood, where it is rapidly reduced to humus by bacteria, fungi, and other agencies. Besides, there must always have been a great number of creatures with bodies too soft and perishable for preservation in fossil form. We hardly expect to find fossil *Amœbæ,* but we look for fossil records of molluscs, whose calcareous shells are more or less durable, and we are not disappointed in our search if we happen to "work" strata where they occur. The fossil record is not complete, yet it is remarkably rich. Indeed, when we think of the passage of time, the stress of the ages, and the nature of the forms of which fossils have been found, we cannot fail to marvel at its richness.

In respect to the gamut of animal life, the witness of the rocks and their contained fossils has at least enabled us to make some broad generalizations. We can speak with certainty of "Ages" when certain types of animals were dominant—of the "Age of Amphibians," the "Age of Reptiles," the "Age of Mammals"—and we can see how reptiles gained the supremacy over amphibians, and the later mammals in their turn came into the ascendant, and drove the reptiles into hiding, many of them into oblivion. And in many ways fossils

EVERGREEN ALKANET (*Anchusa sempervirens*), ORDER *BORAGINACEÆ*.

have enabled investigators to do much more than generalize.

What is true in regard to the scale of animal life is also apparent concerning plant-life. The fossil record furnishes ample proof of development, in spite of the fact that there must have existed in the past a wealth of plant forms of which we have no fossil evidence. We know that in certain geological periods there were groups of plants which were conspicuous and important, but are now extinct. We are sure that certain groups, such as the Club-Mosses (Lycopods) and Horsetails (Equisetums), were once dignified and dominant, and that now their glory hath departed, for such as exist to-day are small and inconspicuous in comparison with their giant ancestors. We know, also, that now is the "Age of Angiosperms," with the odds in favour of the Dicotyledons; that the Angiosperms have asserted their supremacy over the Gymnosperms, which were dominant in the geological "Middle Ages." Ferns have persisted from very ancient times. Many forms that flourished in remote ages are extinct, but they have been replaced by new species, and the group as a whole is probably as flourishing to-day as it ever was in the past. What is particularly remarkable is that fossils representing very remote times indicate groups of plants wonderfully well advanced in their own peculiar lines.

The geologist speaks of Primary and Secondary rocks. The Primary rocks are all igneous, or fire-formed. The original solid crust of the earth must have been made of such, but the term "primary" is applied to all igneous rocks, whether those originally formed, or such as have through the ages been intruded into the crust, or have

issued to its surface by means of volcanoes. Primary rocks yield no fossils. They are crystalline or glass-like; they commonly occur in huge masses, or as sills and dykes, without stratification. It is in the Secondary or Stratified rocks that we look for fossils. These rocks are composed of material derived from broken-up primary masses, and they occur in beds or layers; hence the term "stratified." The gravel, sand, and mud which are being carried by streams into lakes and seas will gradually settle down into beds, and ultimately be consolidated into rocks. The sand will, if not disturbed, become sandstone, and the mud shale. Skeletons of animals and parts of plants included in the deposits may become fossils. Limestones are even now being formed by chemical agency, and also from the mineral remains of corals, molluscs, corallines, etc. What is happening now has happened throughout the ages. Ever since the first land surface was exposed to the elements, the land has been subjected to denudation. Hard rocks have been broken up by frost, eroded by running water, battered by hard fragments borne by wind and wave. Wind has formed dunes from particles of rock, running water has carried pebbles, gravel, sand, and mud, and deposited them in seas and lakes. Earth movements have changed the contour of the land. They have depressed land surfaces, and raised ocean bottoms above the level of the water. Beds of stratified deposits formed under water are now exposed and available to human uses. The fossil-hunter finds in them records of the flora and fauna of the ages in which they were deposited. Earth movements are slow and gradual. They are taking place to-day, although the general

COMFREY (*Symphytum officinale*),
ORDER *BORAGINACEÆ*.

public is not aware of them, and the effects they produce in a single lifetime are not observable. Yet the results of age-long slow movement are stupendous.

In my *Romance of the Rocks* I represented the story of the earth as being, so to say, inscribed in several books, each book containing chapters, and each chapter being composed of sections. The books are made of stone. Each book tells the story of an Era embracing vast time, and each chapter deals with a Period of the Era. Again, each section of a chapter has reference to a subdivision of a Period. But to make the simile correct one must conceive of all the books as being integral parts of one great volume, the theme of which is continuous throughout. We know of no sudden endings or capricious restarts in Nature, no changes of policy, no alteration of law. Development has always been continuous. While for the sake of convenience of description, and for the due relation of older and newer, the geologist speaks of Eras and Periods, he does not imply that one Era is absolutely cut off from another, for he knows that Eras and Periods are not separated by clear-cut lines of demarcation. On the reverse, he realizes that the Periods of an Era shade off one into another, as is also the case with Eras themselves.

Let it be understood that the stratified rocks have been deposited through incalculable time. The oldest of them are so old that it were foolish to even guess their age in years. But we know something of the order in which they were deposited, and their fossil contents enable us to decide which rocks are very old, which are less old, and which are of comparatively recent date. Within the range of the Secondary rocks

there is evidence of a grand procession of life-forms, and, for purposes of classification, and as an aid to intelligent comprehension, the story of that procession is treated of as involving four great Eras:

1. Eozoic (Gr. *eos*, dawn; *zoē*, life).
2. Palæozoic (Gr. *palaios*, ancient; and *zoē*).
3. Mesozoic (Gr. *mesos*, middle; and *zoē*).
4. Cainozoic (Gr. *kainos*, recent; and *zoē*).

The Eozoic rocks are as a book of one long chapter, which we call the Archæan Period. It has been estimated that the strata of this Period are not less than 50,000 feet in thickness. The immense time involved in their deposition staggers the imagination, but we may rest assured that in the progress of that time there was both a coming and going of both plant and animal forms. The lower rocks of the Period consist of igneous and sedimentary deposits, such as the gneisses and schists of the Scottish Highlands, which have been so changed or metamorphosed by stress of earth-movement and other influences that their original constituents have been altered in character. To the fossil-hunter these rocks yield no prizes; he searches in them in vain for vestige of animal or plant; yet they represent an Era of the dawn of life-forms. But those forms, mayhap, were so simple and perishable that they could not become fossilized, or if they did become so, the rocks containing them have since been subjected to such alteration that the remains are not now recognizable. The life and landscape of the remote times represented by these rocks is left to the imagination. In the upper series of rocks of the Archæan Period there are slight traces of life; some seams of limestone amongst them

FIELD SCABIOUS (*Knautia arvensis*),
ORDER *DIPSACEÆ*.

1. Involucre 2. Inner floret 3. Outer floret

are probably of organic origin, and a fossil crustacean has been recognized in rocks of this age in Montana. But to the student of fossil botany all the Eozoic rocks are a blank.

The Palæozoic Era embraces six Periods—the Cambrian, Ordovician, Silurian, Devonian, Carboniferous, and Permian. The Cambrian, Ordovician, and Silurian rocks represent the Older Palæozoic Era, and the Devonian, Carboniferous, and Permian rocks belong to the Newer Palæozoic. To cut a long story short, we say at once that it is not until we come to the Newer Palæozoic rocks that we find fossil plants that throw definite light upon the plant-life of the past, and, curiously enough, it is the vegetation of the Carboniferous Period that is better known to the specialist than that of any Period except the present. The Carboniferous rocks are peculiarly rich in fossil plants. They occur in casts and impressions, and also in petrified forms. In the latter, which have become fossilized under peculiarly favourable conditions, both hard and soft tissues have been preserved, and in microscopic sections the cellular structure is readily apparent. Among these petrifactions are masses of vegetation including fragments of stems, leaves, roots, and seeds preserved in silica, found notably in France; and also the "coal balls" discovered in Yorkshire and Lancashire and in some places on the Continent. These "coal balls" are found embedded in coal seams. They occur as roundish masses of various diameter, usually about the size of an average potato, composed of carbonates of magnesia and lime. They are of particular value to the investigator in that they are petrifactions of masses of plant remains, and include

various parts which can be differentiated by the expert, who by comparison and relation of parts from various coal balls can make a restoration of a particular plant. It is owing to the existence of these pertifactions in coal seams that so much has been learned of the vegetation of Palæozoic times.

The reader may deem it significant that the stratified rocks prior to the Newer Palæozoic have so little to tell us about the plant-life of the past, and he may also raise his eyebrows when he learns that in the Carboniferous strata we find records of plants very well advanced in their peculiar ways. Even in the strata immediately below the Carboniferous—viz., the Devonian (including the Old Red Sandstone rendered classic by the researches of Hugh Miller)—such fossil plants as have been found are very similar to those of Carboniferous times. Some of the main groups of plants now extant were represented in the Palæozoic Era. Are these facts dead against the evolutionary theory? Assuredly not. Following the fossil record from the earliest reliable remains to recent times, we find ample evidence of development—of evolution—and we realize the fact of the total extinction of complete groups of plants in the progress of the æons. And it is unquestionable that the highest plants of all—the flowering plants, the crowning product of the vegetable world—have arisen more recently than any other group. If there is such a dearth of remains of Algæ and other simple plants in rocks older than the Newer Palæozoic—and in the latter we come upon quite complex types—it is not because complex types were primitive; rather ought we to say that these types were better adapted to preservation than the

MOUSE-EAR HAWKWEED (*Hieracium pilosella*),
ORDER *COMPOSITÆ*.

simpler and certainly more primitive forms. Well developed as some of the Carboniferous plants were, those characteristic of the Period were different from any existing species, and, without exception, they are all extinct.

It would have been particularly enlightening to the student of the development of plant forms if the fossil record were such as to indicate an ancient type of plant from which the FERNS diverged; but such an indication is not available. That the Ferns are an exceedingly ancient group appears from remains of Devonian Age; and it is advisable to note that a fossil, *Eopteris*, said to be a Fern, has been found in strata of Lower Silurian times. That this is a Fern is open to dispute. But that highly organized Ferns existed in Devonian times seems beyond question; yet, in the absence of the discovery of petrifactions yielding sporangia, the finding of leaves, no matter how Fernlike, is not sufficient evidence in favour of a conclusion that those leaves are remains of indubitable Ferns. As we have yet to see, many supposed fossil Fern forms, in the light of later investigations, have now to be classed with another group. The point at issue for the moment is that the Palæozoic Ferns, so far as we can learn from fossils, even the earliest of them, were all highly organized on their own peculiar lines, and we search in vain in earlier strata for signs of transitionary forms leading up to them.

Contrary to the notion, in which we used to be instructed, that the Palæozoic Era was the "Age of Ferns," the evidence we now have before us shows that

the alleged dominance of Ferns in the Palæozoic Flora has no foundation in fact. It has been demonstrated that a large part of the Fernlike forms found as fossils are the vestiges of seed-bearing plants, now known as Pteridosperms (Seed-Ferns). The student of fossil plants has now to be exceedingly careful in forming conclusions in regard to alleged fossil Ferns, for unless the distinctive evidence of sporangia, showing a true Fern character, is present, identification is difficult, and it is easy to go astray. But if Ferns were not dominant in Palæozoic times, it is certain they were well represented. There then existed a group, the Botryopterideæ, all the species of which are extinct, and which differed greatly from modern forms; yet it would seem that in their own day and generation they were the leading Fern group. The external characteristics of the group can hardly be decided, but the anatomy of their stems reveals a feature peculiar to all the species. The stems and leaf-stalks (petioles) were monostelic, which means that they were traversed by a single central vascular conducting cylinder. In this respect they differed from the majority of modern Ferns (see Plate XXXII.).

It was in the Carboniferous and the later Permian Periods that the Botryopterideæ flourished, and contemporaneous with them were the members of a second group, the Marattiaceæ (see p. 155); but whereas the former were exclusively Palæozoic and probably prior in appearance, the latter have representatives still existing. But the few living species are not the same as those which throve in Palæozoic times, and the fossil evidence goes to show that the group as a whole was next in importance to the Botryopterideæ in Palæozoic

HEMP AGRIMONY (*Eupator.*

ORDER

1. Single floret, enlarged
2. Head of five florets
3. Bud
4. Seed

with Ferns, are now, after some brilliant researches, proved to have been plants that bore seeds, therein differing from Ferns, which, of course, are reproduced by means of spores. As their name implies, the Pteridosperms were a group of Fernlike seed-plants; in foliage they resembled Ferns, but the seeds they bore approximated very closely to those produced by Cycads (p. 178). A notable feature of the entire group was that both seeds and male organs, which produced pollen, were borne on leaves in all details identical with ordinary foliage leaves. Thus the sporophylls differed from those of Cycads, which are arranged in conelike flowers. The well-known fossil genera, *Alethopteris*, *Neuropteris*, and *Sphenopteris*, erstwhile classed with Ferns, are now recognized as Pteridosperms. The curious combination of Fern and Cycad characters in this Palæozoic plant group suggests that in pre-Devonian times a group of simple plants existed, from which the Pteridosperms and Ferns were developed. The Pteridosperms themselves were probably not in a settled condition, but in a state of flux, and might be characterized as a series of experiments in plant-life which may have found issue in the Cycad flora important in Mesozoic times, and, later still, in the true Flowering plants. From the vast number of their fossil remains, which are particularly abundant in the Coal Measures, it seems that the Pteridosperms formed one of the leading plant groups in Palæozoic times. It is possible that the group lingered into early Mesozoic times, since when it has been extinct. The evidence indicates that it reached its most flourishing condition in the Carboniferous Period, and that in Permian times it gradually dwindled.

CORN SOW-THISTLE (*Sonchus arvensis*), Order *COMPOSITÆ*.

After being taught in our youth that the earliest vegetation known to the palæontologist was entirely cryptogamic, and that seed-plants were only in evidence in later strata, the discovery of the Pteridosperms comes somewhat in the nature of a shock, which becomes the more impressive when we realize that contemporaneous with the group there existed another group of seed-bearing plants, classed as the CORDAITALES. This name has been given to three interrelated families, the Poroxyleæ, Pityeæ, and Cordaiteæ. Of these the last named are best known, the fossil remains being such as to yield a comprehensive view of their characters. In external appearance they seem to have been tall, slim trees ranging from 30 to 100 feet in height; the trunks were unbranched up to nearly the top, where they were crowned by branches bearing long simple leaves having parallel veins. Fig. 70 gives a general idea of the appearance of *Dorycordaites*, which had lance-shaped leaves nearly 3 feet in length, pointed at their tips. Fig. 71 shows a restored branch of *Cordaites lævis*; it indicates the form and arrangement of leaves, which frequently attained a length of 3 feet. The same figure shows inflorescences consisting of many catkins. The stem of *Cordaites* resembled that of a Conifer, with the exception that the pith was much larger, and in size much akin to that of the Cycads. In outward appearance there was little difference between the male and female catkins; the stamens of the former were shielded by bracts, and each consisted of a long stalk surmounted by long, erect, pollen-sacs; in the female catkins the ovules were borne on short stalks and were situated among bracts. The Cordaiteæ were undoubtedly Gym-

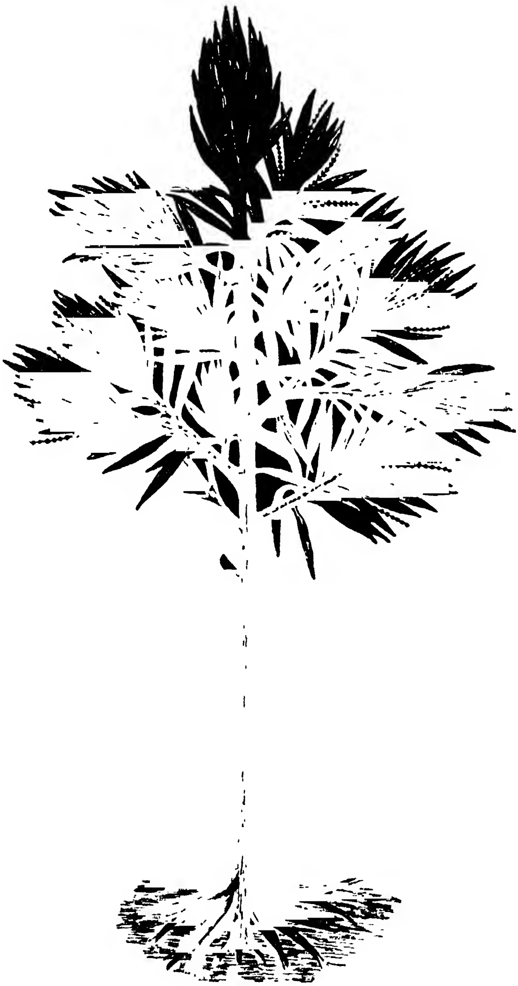


FIG. 70.—RESTORATION OF A SPECIES OF THE FOSSIL DORYCORDAITES. The trunk would be much longer than indicated in the figure.

nosperms, but of a most curious type; their seeds display resemblance both to those of the ancient Pteridosperms and those of modern Cycads; the structure of their stems

reminds us of that of modern *Araucarias* (Monkey-Puzzles and Kauri Pines); and it is declared by specialists

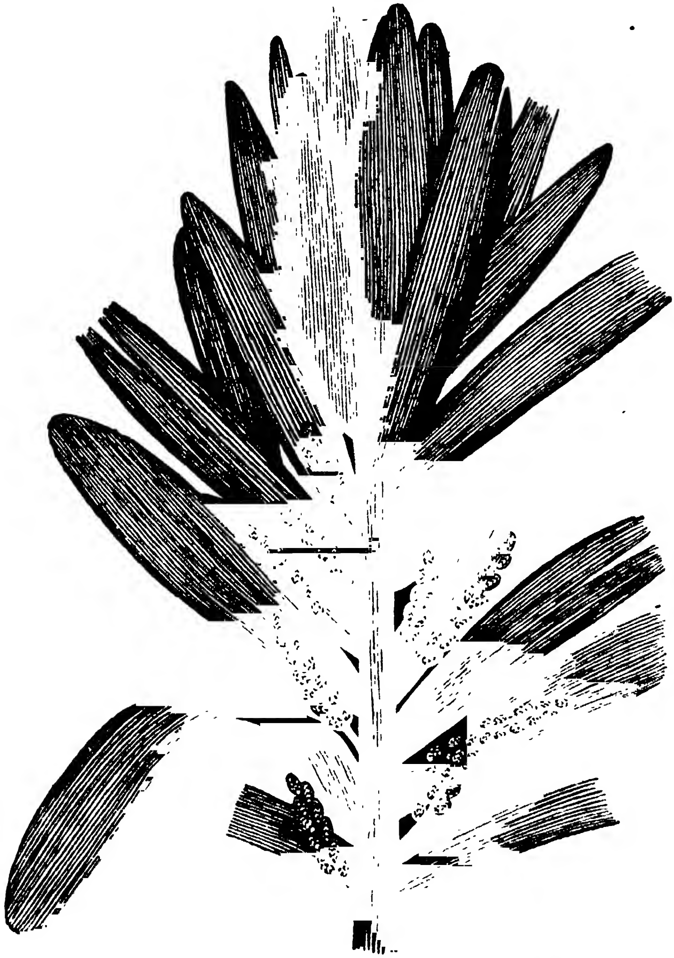


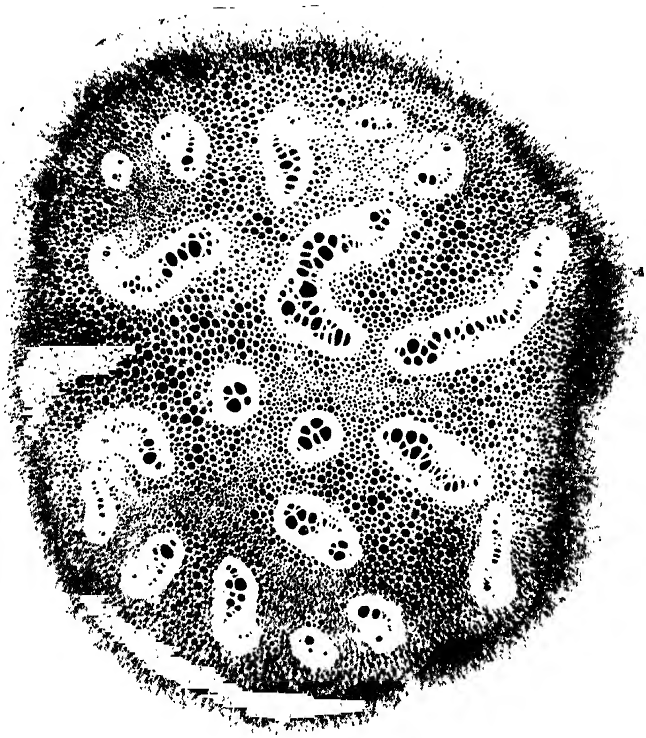
FIG. 71.—RESTORATION OF A BRANCH OF CORDAITES LÆVIS, SHOWING A LARGE BUD AND CATKINATE INFLORESCENCES.

in these matters that their nearest, yet solitary, living representative is the Gingko, or Maiden-Hair tree, which

seems to owe its preservation to the reverence in which it has long been held by the Chinese and Japanese. So far as we can learn from the record of the rocks, the Cordaitales first appeared in Devonian times. They seem to have reached their greatest abundance in the Carboniferous Period; towards the end of that Period they began to dwindle, becoming fewer in the Permian Age, and going out of existence in Early Mesozoic times.

Our brief account of the Palæozoic flora would be incomplete without reference to three other groups of considerable importance—the Lycopodiales, Sphenophyllales, and Equisetales, all spore-bearing plants.

Modern LYCOPODS have already been described (p. 161). In Palæozoic times there was a plant, a genuine Lycopod, to which the name *Miadesmia* has been given; its petrified remains have been found in coal-balls. *Miadesmia* was somewhat like *Selaginella* (p. 163), but it produced something approaching to a seed, and, if it be correct to class it with the Selaginellaceæ, it certainly attained a more advanced condition than has been noted in any of its successors. Very little has been discovered concerning the geological history of the homosporous Lycopodiaceæ (p. 162), but the heterosporous Selaginellaceæ have been traced as far back as the Carboniferous Period. Our living Club-Mosses are but humble representatives of Lycopods, some of which, in Palæozoic times, flourished as big trees in quite royal dignity, and must have been a marked feature of the ancient landscape. The genus *Lepidodendron*, whose fossil remains are so abundant in Carboniferous rocks, embraced Lycopods, some of which attained great size.



TRANSVERSE SECTION OF STEM OF BRACKEN FERN
(*Pteris aquilina*). × 16.

A trunk found in a mine near Bolton, Lancashire, represents a tree that when living must have been about

Fig. 72.—Restoration of Lepidodendron elegans bearing Cones.

140 feet high, the bole, near the base, being fully 3 feet in diameter. The genus was represented in the Devo-

nian, reached its greatest abundance in the Carboniferous, and seems to have tailed off and become extinct in the Permian Period. Many species have been described. A restoration of *Lepidodendron elegans* is shown in Fig. 72. The vertical trunk grew unbranched to a great height, and was crowned with repeatedly two-forked ramifications. The leaves, which were linear, or needle-like, were, in some instances, about

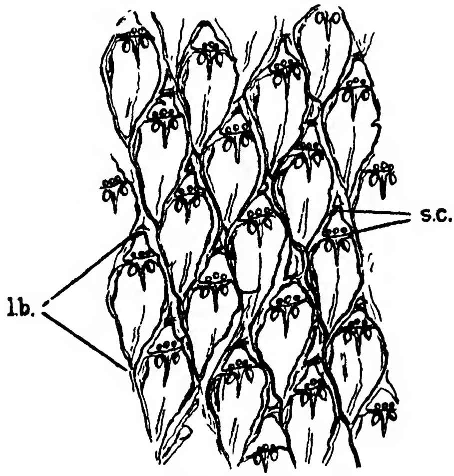


FIG. 73.—LEPIDODENDRON VELTHEIMIANUM: PART OF STEM-SURFACE. *l.b.*, Leaf-bases; *s.c.*, leaf-scar.

6 inches long; they were spirally arranged on the young stems and branches, being seated on rhombic leaf-cushions. These leaf-cushions were persistent, and it is they which give the characteristic appearance to the pieces of stems which are so well known to fossil collectors (see Fig. 73). The fructifications were conelike, and borne on the ends of branches or on the stem; they consisted of sporophylls protecting sporangia. It has

been demonstrated that some species were heterosporous, and this was probably the case with all.

Of no less importance and distinction in the Palæozoic flora than the giant Lycopods just described was the genus *Sigillaria.* It included different species of tree-like Club-Mosses, some of which were equally as lofty as the tallest Lepidodendrons, while others appear to have been more stout and stumpy. *Sigillaria reniformis* was of the latter habit. A trunk found in Germany is described as being 6 feet in diameter at its base, but it tapered off rapidly to a diameter of 1 foot at the height of 18 feet. Another trunk, found in France, near Valenciennes, for a length of over 70 feet was almost cylindrical. At the lower end it was about 2 feet in diameter, while at the other extreme it was 1 foot 8 inches; it was entirely unbranched. It would appear that as a rule the *Sigillariæ* were lofty trees with scantily branched, pillar-like stems and linear leaves, which were, in some instances, over 3 feet in length. The fructifications were conelike, about 9 inches long; they were borne on long stalks attached to the stem, and consisted of spirally arranged or whorled sporophylls protecting sporangia. The leaf-scars, which, like those of *Lepidodendron*, are conspicuous in the fossils, differ in their arrangement from those of that genus. They are arranged in vertical order, as shown in Fig. 74, whereas in *Lepidodendron* the arrangement is oblique or spiral. The distribution in time seems to have been more restricted in *Sigillaria* than in the *Lepidodendra;* the former have not been traced with certainty below the Carboniferous, and they probably died out in Permian times.

The name *Stigmaria* has been given to fossil roots, which are frequently found *in situ* in the " under clay " below coal-seams. Fig. 75 depicts a stump with attached roots found in Yorkshire, and preserved in the University Museum in Manchester. The diameter of the stump is 4 feet 4 inches, and the root-spread is about 30 feet. In the absence of fossil remains other

FIG. 74.—SIGILLARIA MAMILLARIS: PART OF STEM-SURFACE.
l.s., Leaf-scars; *c.s.*, cone-scars. Note vertical ribs.

than the roots classed as *Stigmaria*, it seems impossible to determine whether they belonged to *Sigillariæ* or *Lepidodendra*.

Modern EQUISETALES, or Horsetails (p. 157), all embraced in the genus *Equisetum*, are the living representatives, but few in number, yet by no means lacking in virility, of a great race of plants which were highly developed and very numerous in Palæozoic times. Indeed, in the history of the Equisetales we have an example of a race's degeneration—that is, if it be

PLATE XXXIII.

COW-PARSNIP (*Heracleum Sphondylium*), ORDER *UMBELLIFERÆ*.

allowable to apply such a term to a group of plants which is now less complex in structure and fructification, and has not anything like the stature of its extinct ancestors. But, although the glory of the race has departed, its existing remnants can evidently hold their own, as the gardener who has to cope with the incursions of *Equisetum arvense* has reason to know. We may say of *Equisetum limosum* that it is breaking bounds. It does not seem to be content that its kind should dwindle

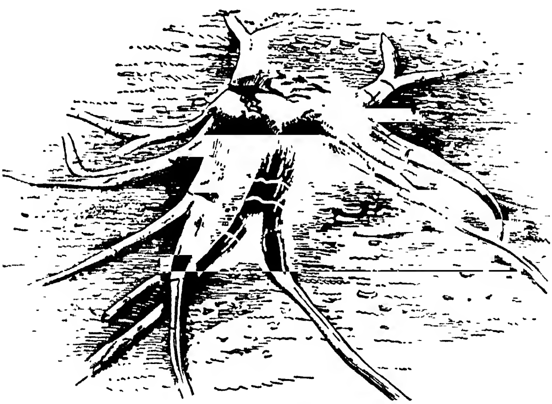


FIG. 75.—STIGMARIA FICOIDES.
From coal-measures in Yorkshire.

to extinction, but it is now on conquest bent. I have observed within the last few years how it is invading Highland tarn and Lowland pond, and becoming quite dominant in marshy places.

Fossil Horsetails are generally called "Calamites," the name of the genus *Calamites* (*calamus*, a reed), which was the most important of the Palæozoic genera. The investigation of their fossil remains has yielded a considerable and almost complete mass of information

in respect of the Calamites. Whereas to-day the tallest species of *Equisetum* is not more than 20 feet high, and at that must needs have support to maintain the perpendicular, so slender is its stem, there were among the Palæozoic Calamites species which attained the majesty of forest trees. It is known that some of them grew to a height of at least 100 feet, and had shafts up to 4 feet in diameter. In general habit they resembled modern Horsetails. Their stems were hollow, and for the most part were composed of tissue much softer than is usual in trees; but this softness was compensated for, and the trees were rendered self-supporting by a development of secondary wood, which does not occur in living Horsetails, or, for that matter, in any plants lower than the Gymnosperms. Whorls of branches grew from the nodes of the stem, and alternating with these were whorls of lanceolate leaves with their bases united into a sheath. In *Archæocalamites*, a very ancient type dating from the Devonian Period (see Fig. 76), the leaves were more fully developed, having dichotomous (two-forked) subdivisions. In some Calamites the cones were in structure very similar to those of modern forms, but in the majority they were more complicated, and had, alternating with the sporophylls, whorls of scale leaves. As a further mark of advanced development in Palæozoic times, it is noteworthy that some of the Calamites produced mega- and micro-spores—*i.e.*, they were heterosporous. In this respect they differed from modern Horsetails, which, it will be remembered, produce spores only of one kind. If the reader can imagine in the country around him the existence of a goodly number of Horsetail plants magnified to fifty times the

CHICORY (*Cichorium intybus*),
ORDER *COMPOS*

1. Radical leaf 2. Lower leaf and ste
3. A floret enlarged

size of an average modern species, he will be able to form some sort of a mental picture of the peculiar cast which the Calamites would give to the Palæozoic landscape. Since the halcyon days of the Calamites, which were in greatest abundance in the Carboniferous Period, the Equisetales as a group have gradually dwindled in size and importance, and we know from the few existing species how extensive the falling off has been. The group has displayed a tenacity which commands our respect, and one cannot avoid admiration for a race which has survived the chances and vagaries of many æons, and whose existing forms are the representatives of an aristocratic ancestry.

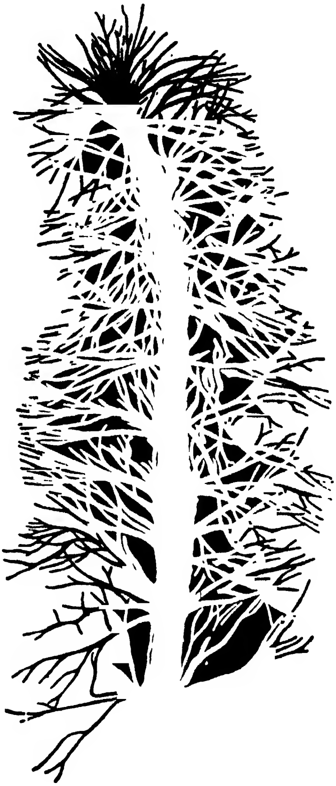


FIG. 76.—ARCHÆOCALAMITES RADIATUS. BRANCH WITH LEAVES IN WHORLS; LEAVES WITH REPEATED TWO-FORKED DIVISIONS.

A glance at the SPHENOPHYLLALES will terminate our review of the chief Palæozoic plant groups. In the absence of the researches of palæobotanists, we should certainly have had no knowledge of the Sphenophylls. They seem to have arisen and become extinct in the

course of Palæozoic times, and there are no modern plants which would lead us to suspect their existence in the past. So far as our knowledge goes, it seems to indicate that the Sphenophylls did not form an extensive group, but their fossil remains are of great interest in that they demonstrate the existence of a plant group intermediate between the Horsetails and Lycopods. The genus *Sphenophyllum* (Gr. *sphēn*, a wedge; *phyllon*, a leaf) was dominant in the group, its earliest traces being found in Upper Devonian strata. The fossils indicate delicate stems, probably of climbing habit, and it has been suggested that the plants scrambled over other vegetation, using it as a support, in much the same way as is exhibited in our modern Bedstraws—for example, the Goosegrass, or Cleavers (*Galium aparine*). The stems were ribbed, and furnished with whorls of leaves at considerable intervals The leaves were commonly, but not invariably, wedge-shaped, generally six in a whorl, and attached by their points to the stem. The fructifications were in the form of cones, resembling somewhat those of Calamites. The Psilotaceæ (p. 163) are considered to be what may be called a modern suggestion of this ancient group. Possibly the Lycopods, Sphenophylls, and Equisetales evolved from a common ancestry, of which we have no fossil record; but where full evidence is lacking, we can only speculate, and it were unwise to dogmatize.

We have a unique knowledge of the vegetation of the Carboniferous Period, because of the rich fossiliferous character of the Coal Measure deposits. The wealth of fossil plants obtained from these deposits must not,

TUTSAN (*Hypericum Androsaemum*),
ORDER *HYPERICACEÆ* St. John's-wort family

1 Fruit 2 Calyx and young fruit

however, lead us to hasty conclusions. It is probably due to the existence of conditions highly favourable to fossilization. In prior or succeeding times many types of plants may have existed of which we have no trace, because the conditions in which they lived were not favourable to the preservation of their remains in fossil form. The very richness of the Coal Measure fossils is, however, an excellent argument in favour of a definite assurance in regard to the Carboniferous flora. Seeing that Coal Measure times were so favourable to preservation of plant remains, we may rest assured that the fossils already discovered are a clear indication of both what there then was and was not of plant-life. Had, say, true Flowering plants lived in that remote period, plants such as the Oak or the Sunflower, their remains would have lent themselves to fossilization quite as easily as those of a Calamite or a Fern. The Carboniferous fossils, indeed, give us a fairly clear vision of the dominant vegetation of the Period they represent. There were spore-plants, represented by the Ferns, Lycopods, Horsetails, and Sphenophylls, but there were two remarkable groups of seed-plants—the Pteridosperms and Cordaitales. Of the higher Flowering plants, the Angiosperms, there were none. The general colour scheme of the Palæozoic vegetable kingdom must have consisted of tints of green, relieved maybe by touches of russet; but certainly the landscape was not beautified by the bright yellow, reds, and blues of flowers as we know them. The record of the rocks also helps us to realize that as there were no gay flowers advertising free sips of nectar by the flaunting advertisement of brilliant colour, so also there were no nectar-loving insects.

Dragon-Flies, some of them very large, and Cockroaches seem to have been principal among the insects contemporaneous with the Seed-Ferns. Nature had not yet attained to Butterflies, Moths, Bees, or Wasps. It is curious that in much more recent strata—the Cretaceous—we find traces both of Angiosperms and of those insects which visit them for nectar and pollen, and act as pollinating agents. Insects have played an important part in the evolution of entomophilous (insect-loving) plants, and, on the other hand, the evolution of insects must also have been affected by plants which flaunt the lure of nectar.

In the most recent Period of the Palæozoic Era—the Permian—we find signs of change; indeed, the Permian Period was one of marked transition. Ferns as a group held their own, as they have done even to modern times; but the other groups, so dominant in Carboniferous times, began and continued to dwindle. The Conifers (p. 180), dominant among modern Gymnosperms, can be traced back with certainty to Permian times, and it is possible that in *Walchia*, of which fossils of leafy twigs, with a habit resembling that of certain modern Araucarias, are frequently found, we have evidence of Conifers in the higher Carboniferous strata. Forms allied to living genera of Conifers occur in Permian rocks, and these seem to have increased as the Period advanced. In an age when the great Carboniferous groups were waning, the Conifers were "enlarging the place of their tent," and at the same time a new group—the GINKGOALES—were coming into prominence. As I have already stated (p. 233), the genus *Ginkgo* has now but one

PLATE XXXVI.

GARLIC MUSTARD, or JOCK-BY-THE-HEDGE (*Sisymbrium alliaria*).
ORDER *CRU*

1. Plant with young flower 2. Older flower 3. Fruit

the Arctic and Antarctic regions, indicating a warm climate where now snow and ice prevail.

Modern Cycads, particularly of the genus *Cycas*, have been found fossil, but in speaking of Mesozoic Cycads we refer to a vast group of many genera, which we more aptly designate "Cycadophytes," and of which the great majority appear to have been much more highly organized than the relatively simple modern forms. I am referring to the Bennettiteæ, which were much like existing Cycads in general habit, but differed from them in a marked degree as to their reproductive organs. In the Cycads of to-day the sexes are represented on different plants, but in the Bennettiteæ the cones, borne laterally, and of a flower-like appearance, were hermaphrodite—that is, they included both sexes. We may, indeed, speak of the cones as "flowers," for they consisted of bracts, staminal leaves bearing many pollen sacs, and stalked ovules, which, after fertilization, developed into seeds of the dicotyledonous type. Here, indeed, we have a suggestion of true Flowering plants, and it is possible that in the fossil Bennettiteæ we have an evolutionary side issue from the main stock which ultimately yielded the Angiosperms.

As to the all-important Angiosperms themselves, we find fossil remains of both Monocotyledons and Dicotyledons in Upper Cretaceous strata, but the fossils are principally impressions of leaves, not petrifactions; hence determination of species is difficult. It is interesting to realize that in the later Mesozoic we come suddenly upon Angiosperms, which increased as the Cycadophytes and other groups waned, and which, through Cainozoic to

WATER AVENS (*Geum r*

ORDER *ROSACEÆ*

existing times, have made marked progress and become dominant.

Our rapid review of the plant groups of the past, made possible by the magnificent work of specialists in fossil botany, certainly impresses upon us the truth of the poet's dictum: "The old order changeth, and yieldeth place to new." It also throws some light on the problem of development—perhaps sufficient to make us intellectually humble. We have yet much to learn from the fossil record, and probably there is much that we wish to know that we shall never know. Yet we must needs marvel that so many plant-traces have survived the chances and changes of countless ages. There is in life "a strange coming and going of feet." The principle involved in this statement is fully illustrated in human history and in Nature. "Kingdoms come and go, Empires rise and wane." It may not be inapt to apply the term "imperial" to some of the Palæozoic plant groups, yet three of these are extinct, and two—the Lycopods and Horsetails—are no longer imperial. Concerning all these, one may exclaim: "How are the mighty fallen!" Nature, pressing on to high fitness and perfect adjustment, evidently "scraps" archaic machinery, and meets changed conditions with changed or specially adapted life-forms. Researches into the history of the plants of the past, as well as knowledge of the lack of finality and absolute fixity of present plant forms, suggest that as there has been change in the past, so there may be change in the future. Nature has not exhausted her resources in the development even of the highest Angiosperm. Given external conditions to act as stimuli, we

may be assured that living protoplasm is fully capable of response, and that in Life itself there are potentialities which will lead to wonderful results.

In concluding this chapter, we have to make a brief note concerning fossil remains of some of the lower and humbler plants. It has been claimed that traces of Bacteria have been detected in association with other plant fossils, even in those of Carboniferous Age, but the evidence for the claim is not sufficiently convincing. Diatoms have been traced back to the Jurassic. They are plentiful in Cretaceous and Cainozoic strata. Their siliceous shells lend themselves to preservation, and if they had been an ancient type of plant, we might certainly expect to find them at least as far back as the Palæozoic. The fact that we do not find them until the Upper Mesozoic suggests that they are by no means primitive, but a distinctly late product of plant-life. Remains of Seaweeds are attributed to Silurian times, but many impressions on rocks, claimed by some to represent Seaweeds, fail to carry conviction to the unprejudiced mind. Coralline Seaweeds, coated as they are with calcareous matter, lend themselves to fossilization, and many such are found fossil in Mesozoic and Cainozoic strata. The Characeæ, a curious and anomalous group of water plants found in ditches, brackish water, ponds, etc., and known as Stoneworts, are cryptogams. They deposit calcareous matter in their cell-walls, and hence are also good subjects for fossilization. Their stems and also spore-fruits are found fossil in Cainozoic strata. The lower Fungi are detected in connection with Carboniferous plants, their hyphæ being so excellently preserved in petrifactions that they can be

traced progressing from cell to cell. The Coal Measure petrifactions yield no trace of Mosses, but there are impressions of these plants in strata of later age. Remains of Liverworts are scanty, and such as have been found, the most common being called *Marchantites*, throw no light on evolutionary problems.

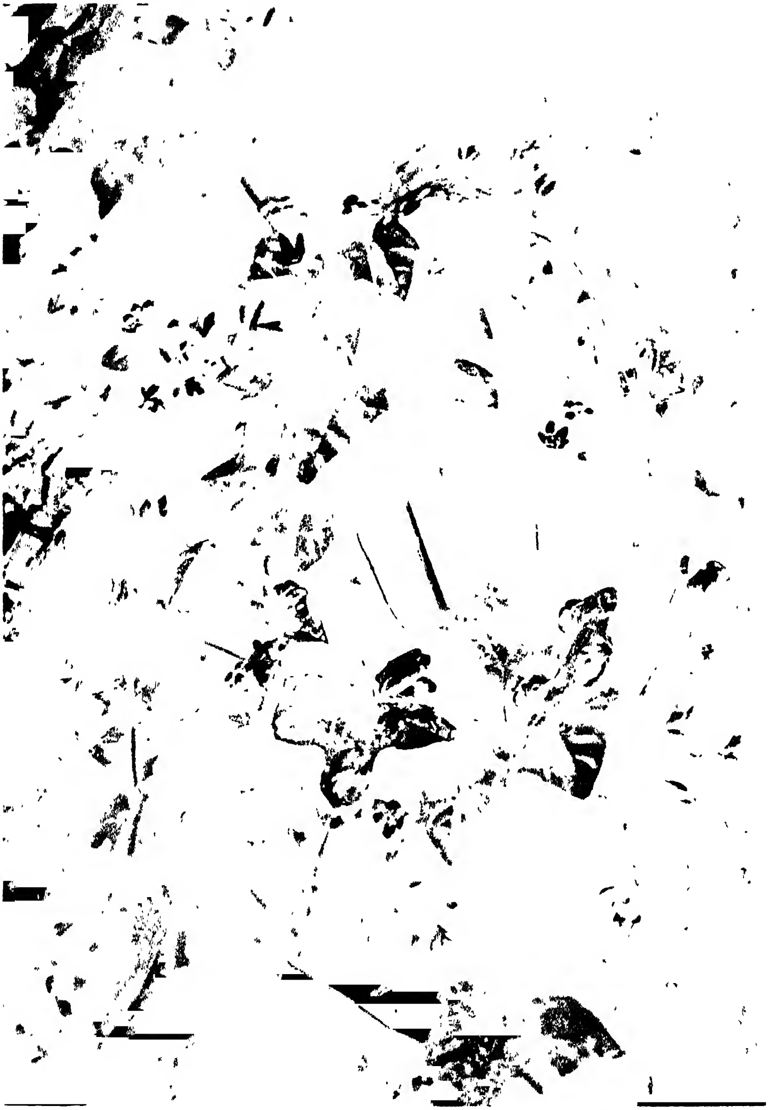
CHAPTER IX

THE FOOD OF PLANTS, AND HOW THEY SECURE IT

"SELF-PRESERVATION is the first law of life." So runs a truism hoary with antiquity. For lack of a better way of putting it, the assertion is ventured that deep down, and ineradicable in the living plant, is the impulse to live—an impulse which involves not merely self-preservation, but also the effort towards racial immortality. Where there is life there is also growth, and, moreover, reproduction. In reproduction the parent plant may seemingly perish, and "leave not a wrack behind," but, in truth, its potency is transmitted to posterity. As to its outer garb, it returns to Mother Earth; but as to its inward mystery, it lives still in its progeny.

In order that plants may live, and consequently grow and propagate their kind, they must be suitably nourished, and, in addition, defended against influences inimical and fatal to the welfare of their vital protoplasm. The defences of plants will receive consideration later. Our subject for the present is the food of plants, how it is secured and utilized.

The vital unit of plants is the protoplast, the little protoplasmic body which is truly the "cell," and includes all the living constituents—nucleus, chloroplasts, etc.—of the cell. A one-cell plant, such as a Desmid



WHITE BRYONY (*Bryonia dioica*), ORDER *CUCUR*

Climbing over a hedge

(p. 31), or a *Chlamydomonas* (p. 52), is a single protoplast fully equipped for existence in a particular environment. Multicellular plants are aggregates of protoplasts operating in community to mutual advantage, and for the benefit of the individual plant of which they are the living parts. The cell body, or protoplast, secretes a cell wall which serves as a protective covering, and also provides a degree of stability for the living unit. Consequent upon the absorption of nutrient material, and owing to its inherent vital activity, a cell grows. When growth has proceeded to a maximum beyond which distention of the protoplast would be dangerous, the cell divides, and it is essential for us to appreciate the fact that the growth of a multicellular plant involves the continual increase of protoplasts. In the ordinary course of thought we regard a flourishing Oak as a living plant unit, but in point of fact what we see outwardly is a wonderful habitation erected by milliards of microscopic protoplasts. The Oak is due to the aggregation and repeated multiplication of these vital units. It is their home and their chemical laboratory. The wood which gives it stability is composed of the hardened cell walls of these industrious builders. In our previous study of the one-cell plants we have observed that the growth of the unit, which eventuates in division, leads to an increase of individuals similar to the parent form, and sufficient unto themselves. Moreover, we have seen that propagation and vitality are stimulated by the sexual act. In such plants the sexual act may take place between any individuals, but in the multicellular plant the cells multiplied by division remain in association, instead of separating into independent units. They

co-operate in building up "the plant," and certain of them are told off for particular work. All are chemists, but some specialize in one way and some in another. There are carbon-assimilators in the green leaf, workers in salts in the root hairs, sap-carriers in the vascular tissues. In such a community the business of sex is not transacted promiscuously among any of the cells, but some are specially developed and told off for the duty.

It is, then, the living protoplast that promotes growth, and in order to do so must be nourished with suitable food. The requirements of a plant are those of the protoplasm which constitutes it. We shall now decide the nature of these requirements.

We have every reason to believe that living protoplasm came into existence in water, and that the earliest life-forms, both animal and vegetable, flourished in that medium. To say that land plants, now far removed from their aquatic ancestry, cannot live without water, is stating common knowledge, for plants insufficiently supplied with water droop. If the drooping individuals are furnished with water before it is too late, they revive, and become erect and tense; and if the supply is withheld too long, they wither and perish. But it is not realized by the unscientific observer that the water required by land plants is really demanded by the protoplasts that form them and control their existence. Protoplasm cannot operate in what the Scotsman calls "drouth." If moisture is not sufficient, it must suspend activity; and if desiccation occurs, it must die. In fact, in spite of its conquest of the land, protoplasm has never rendered itself independent of water. If it

Plate XXXIX

WALL PENNYWORT (*Cotyledon umbilicus*).
Order *CRASSULACEÆ*.

1 Flower, opened and enlarged   2 Flower, in natural position

constructs the form of a land plant in which it may operate, it must take care that the structure is such that it may draw and hold the moisture which is necessary to its being. There be land plants and water plants, but we cannot say there is land protoplasm and water protoplasm, for this vital substance, wherever it may thrive, can do so only in, and by means of, the medium in which it had its birth.

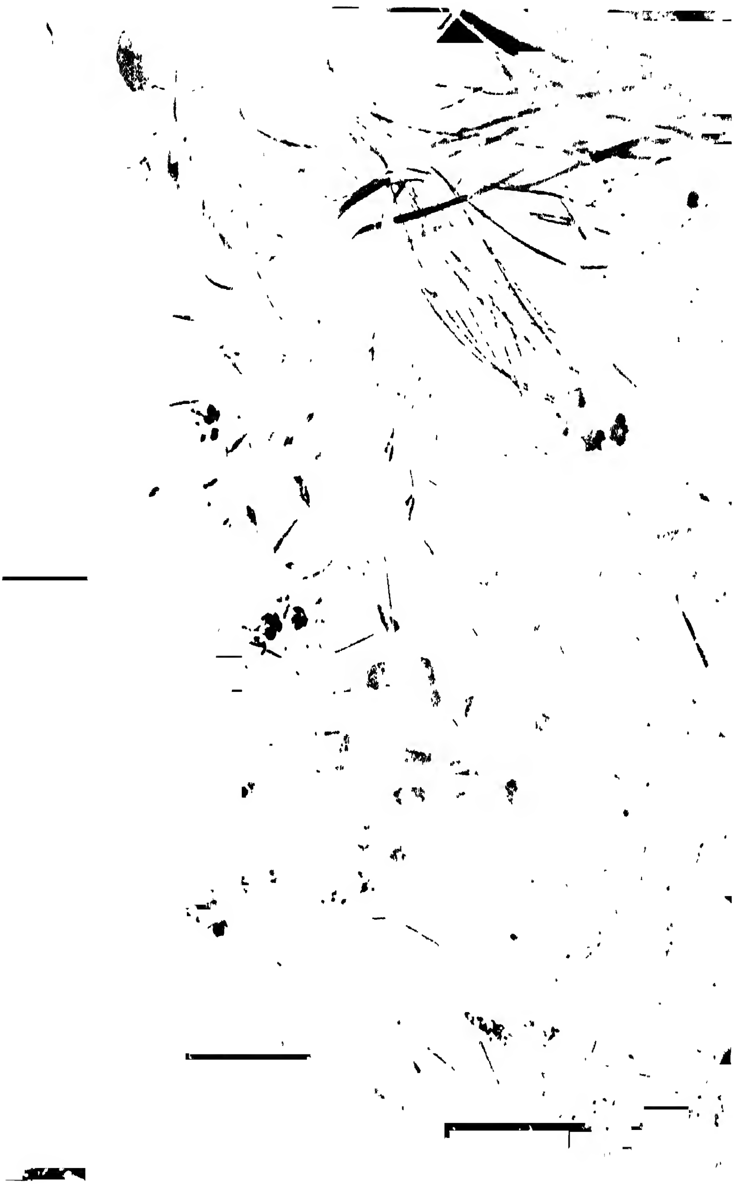
Water constitutes nearly 50 per cent. of the weight of the woody parts of plants, and in juicy herbs the percentage of water is from 70 to 80. The proportion becomes higher in succulent plants and fruits, varying from 85 to 95 per cent., while in aquatic plants it rises to from 95 to 98 per cent. It is apparent that if we are to know anything about the life of a plant, we must study it in relation to its water-supply.

We decide that water is of importance to the protoplasts of a plant as a medium in which they can operate, and which so permeates them that they are maintained in a sufficiently elastic condition and also energized. But water has other important uses, for it conveys valuable mineral salts in solution for the use of the little protoplasmic chemists. It is a transporting agent of the products of their chemistry, and, again, it is an actual food, for the elements of which it is composed—hydrogen and oxygen—are utilized in the preparation of nutrient organic compounds. Cells sufficiently supplied with water are turgid, and render a plant rigid. The effect of the turgidity of cells is well illustrated in the commonly cultivated Hydrangea. This plant in warm weather transpires freely, and uses much water. So long as the supply is sufficient, its leaves are rigid,

because the cells are turgid. An insufficient supply is quickly demonstrated by limp and drooping leaves—a phenomenon due to the fact that the cells are not turgid.

Owing to different conditions of the water-supply, there are marked differences between land and water plants. A true aquatic lives and moves and has its being in water. It has no need to develop special means for water absorption, because it can imbibe all it requires through its general surface. It is for this reason that a Seaweed has no root. Water and nutrient salts in solution are absorbed through its surface, and even the carbon dioxide and the air that it requires are present in the water. Hence an aquatic plant has no stomata. Water plants have little need for a vascular system, either for conduction or for support. They are supported by the water, and vascular bundles are either poorly developed in them or non-existent. Certain lowly land plants, which are not far removed from aquatics, and which favour moist and shady situations, can also absorb water through their general surface. Liverworts are examples.

We opine that land plants have evolved from water plants, and in previous inquiries we have considered the advance in structure demanded in the conquest of the land; but it has happened in the great struggle for existence that land plants have been jostled into water, and have learned how to make themselves at home there. We may assume that all flowering aquatics are descended from land plants which accommodated themselves to the demands of an aquatic environment. Among such are the Water-Lilies, whose leaves are long-



COMMON SPEEDWELL (*Veronica officinalis*), Order *SCROPHULARIACEÆ*.

stemmed, and rest on the surface of the water, and can be accommodated without inconvenience to changes of its level. Stomata are in land plants usually developed most freely on the under surfaces of the leaves, but in the Water-Lilies they are on the upper surface of the leaf, and consequently exposed to the air. They could not be effective otherwise. Provision is also made that the surface of the leaf shall not be inundated, lest the stomata be rendered inoperative. There are plants found in aquatic conditions that have two kinds of leaves. The Water-Crowfoots are examples. They have floating leaves, with the upper surface exposed to the air, and submerged leaves very finely divided. The latter offer little resistance to moving water, and hence are not liable to be torn thereby, and they provide increased surface for the absorption of carbon dioxide and oxygen. The floating leaves are lobed, but not dissected. They expose a broad surface to the air. If the water in which the plant lives dries up, the submerged dissected leaves die, but the floating leaves continue to live and carry on their useful functions. The Bladderworts (*Utricularia*) in all European species have dissected submerged leaves, and no roots. They float in the water. The leaves can absorb nutrient substances in solution, as well as carbon dioxide and oxygen. Their flowers only are aerial. Roots in their case are not needed.

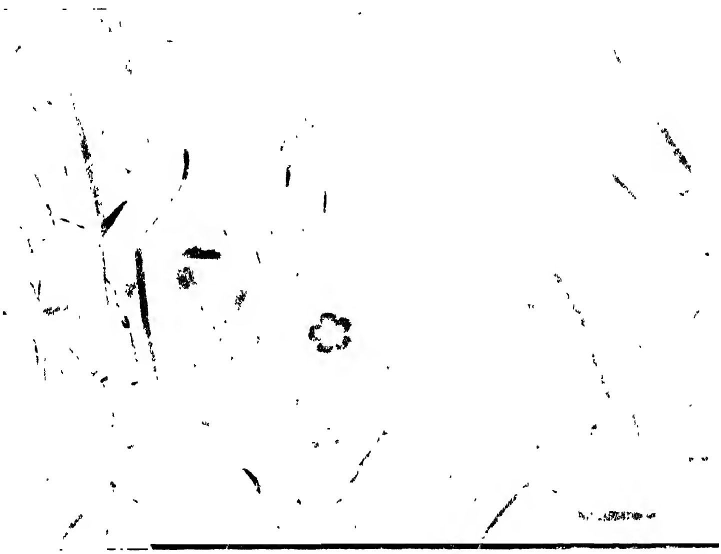
Water plants, then, have no difficulty as to water-supply, unless it be in its superabundance; but land plants of all the higher forms have had to adopt special means of water absorption and retention. They cannot absorb a supply by their general surface. Were they

able to do so, they would lose by evaporation as rapidly as they gained. In their case evaporation is essential to circulation of moisture in their tissues, and their surface, exposed to the air, is of such a nature that, under normal conditions, evaporation can take place only at an advantageous rate. The very devices, such as cuticles permeated with resin or wax, which lead to retention of water and prevention of undue evaporation, are in land plants inimical to absorption by the general surface. In brief, the land plant of the normal type is dependent for its water-supply upon such as is held by the soil, and it absorbs all it requires by means of a special feature of its structure—its root hairs. Soil has a considerable capacity of holding water by capillarity, which prevents it from draining off. Sachs states that sand in this way retains 21 per cent. of water, loam 52 per cent., and ordinary cultivated soil 46 per cent.

We understand that what in Seaweeds is often mistaken by the casual observer for a root is merely a holdfast. It does not absorb food material from the rock to which it is attached. We may also assume that the root of a land plant is a holdfast, a means of fixity in the soil, but it is a holdfast which has formed the habit of sending out filaments of protoplasmic cells into the water-containing soil. Among the water plants which originally set out to conquer the land and colonize it, those which managed to form a vital connection with the soil by means of root-hairs, as these filaments are called, were destined to be the forerunners of highly complex and successful land plants. For in these the development of the root-hair, which can explore the soil in quest of moisture, and absorb it through its cell

PLATE XLI.

CREEPING CINQUEFOIL (*Potentilla reptans*), ORDER *ROSACEÆ*.



FIELD CHICKWEED (*Cerastium arvense*), ORDER *CARYOPHYLLACEÆ*.

wall, is the solution of the water-supply problem, and along with it of the means of obtaining other nutrient substances. And such a solution sets the aerial portion of the plant free to protect itself by various devices against the ravages of heat and cold, of drought, of bacteria and beast.

I think it was Darwin who compared the root-tip to the brain of an animal. The manner in which it insinuates itself into rock crevices, negotiates stones, and searches the soil for its richest supplies, is certainly suggestive of sagacity. The root-hairs cling to particles of soil enveloped with films of water containing dissolved mineral salts. Sometimes they clasp these water-coated particles so tightly that they can only with great difficulty be removed. We can see this when we pull up seedlings, which always bring soil along with them, and can never be pulled " clean."

But if the leaves of these normal land plants cannot absorb water by their surface, and it is inadvisable that they should, their arrangement and form is usually such as to make them conduct and turn off from their surface the rain-water which falls upon them, and to cause it to fall on the ground in positions where it is most acceptable to the roots; or perhaps it would be more in accord with the facts to say that the roots reach out to the area of the soil which is kept moist by water dripping from the leaves. Let us use the common cultivated Beet, familiar to all, to illustrate our meaning. The stout, fleshy, tapering root descends vertically into the soil. It gives off short, thin branches, which never extend far beyond the main root from which they originate, and it is these branches which are furnished

with absorptive root-hairs. It is evident that such a root requires a good deal of water, and is adapted to deal with it in the limited area of its central and vertical position. The leaves are beautifully constructed, and arranged to meet the requirements of the roots. Their stalks converge to a common centre, and are deeply channelled on their upper surface. The broad blades constitute a considerable water-collecting area, and their venation is such that water is conducted by side or tributary channels to the main channel, and thence along the deeply channelled stalk to the common centre, the top of the root stock. The leaves are placed at an angle which insures that the great bulk of the rain-water falling upon them shall be conducted by their natural gutter system to the central position, where it is in great demand. The Rhubarb plant is another example of the same centripetal conduction of water, and so also are the Parsnip and the Carrot.

We take shelter under a Sycamore or a Chestnut-tree during a shower of rain, knowing that but little of the water will reach us; but we can watch the raindrops falling from the leaves in a circle about us; and while we are waiting and thinking, we may realize that the water is reaching and saturating a circle of ground occupied by the finer ramifications, furnished with root-hairs, of the spreading roots. The "spreading chestnut-tree" of the *Village Blacksmith* has a spread of roots extending to an equality with the spread of the leafy branches. The roots, indeed, reach out to the circle of earth moistened by the "drip" from the leaves, and the water falls just where it is in special demand by the roots.

The leaves of a Sycamore or a Chestnut have a con-

SILVERWEED (*Potentilla anserina*). ORDER *ROSACEÆ*.

siderable surface, and in the aggregate form an excellent canopy, wherefore we are not surprised at finding shelter under them. But we can secure equally as satisfactory shelter under a Pine or a Larch, and when we remember the needle-like form of the leaves of these Conifers, we are disposed to wonder that the ground is always so remarkably dry beneath them. But their branching and leaf arrangement is such that most of the rain which falls upon the trees is always turned outwards, very little making its way down the trunk.

The Mulleins (*Verbascum*) have a tap-root, and the outline of the aerial part of the plant is that of an attenuated pyramid. The leaves at the base are larger and broader than those above; indeed, it is to the gradual decrease in the size of the leaves from base to apex that the plant owes its tapering form. If we look down upon a Mullein from above we can see that if the stem could be "telescoped," the leaves would come together in the form of a rosette, and, moreover, that the actual leaf arrangement of the plant is that of a rosette with an elongated axis (the stem). This arrangement is excellent both in relation to light and air, and to falling rain. The short upper leaves turn water outwards, and it falls from their apices on to the blades of leaves under them. These under leaves are somewhat longer, and turn the water, so that it falls on to those below, which in turn are also longer. Eventually the water reaches the lowest leaves, which are longer and broader than all, and so tilted that the bulk of the water that reaches them from the upper leaves is turned *inwards*, so that ample water reaches the neighbourhood of the tap-root.

But we are not to decide rashly that leaf arrangement has an invariable relation to the need of conducting water to the absorptive area of the root. It is obvious that such a relationship does not exist in marsh or water plants, whose roots are abundantly supplied with water, and have no need for a special gutter system in the leaves, leaf-stalks, or stems, even if such seems to exist.

We have already stated that the root of a plant is primarily a holdfast. It secures for its possessor a local habitation and a fixity of tenure which varies in proportion to the particular requirements of the case. An annual plant, one that develops and perishes in a single season, has a light grip of the soil, yet one that is sufficient for its needs; but a perennial plant takes care to secure a most tenacious grip of the soil, that grip being the firmer in accordance with the larger growth of the subject. Quite recently I clambered over rough ground bestrewn with hundreds of fallen Conifers which had been laid low during a very heavy gale. Among all these fallen trees I did not notice a single one whose trunk had snapped under stress of the wind. They were all uprooted, and so tenaciously had they gripped the soil by the intricate ramifications of their roots, that in each case a huge mass of soil had been lifted and carried by the tree when it fell. Although it was more than two years since the day of this disastrous gale, many of the trees when I observed them were actually growing, evidently on the strength of the soil so firmly held by the root system.

The effective root-hairs (Fig. 77) are exceedingly fine, with a diameter not exceeding that of a medium-sized

cell, but having a length which may reach to several millimetres. They are scarcely visible to the naked eye. They stand out straight from the epidermis, and occur in a zone just above the active growing-point not only of the main root, but also of its branches. As the tip of the root advances with growth, new root-hairs are produced, and the older ones behind them wither, so that the effective hairs always occur in a zone very close to the root tip. The older portions of the root, which become woody and invested with cork, do not absorb

A

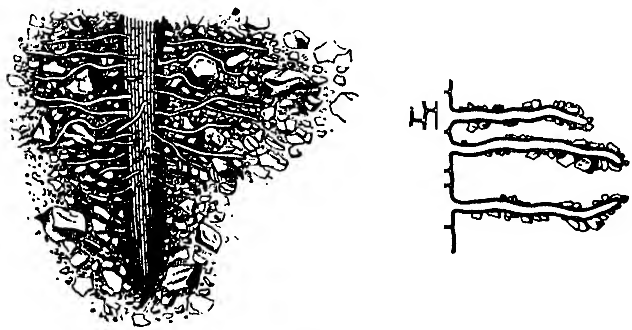


FIG. 77.

A, Young root, with root-hairs penetrating the soil (× 7); *B*, root-hairs, under higher magnification, showing adherent particles of soil.

water. They grip the soil, and hold the plant fast in its site, and their hold is such that no ordinary strain will dislocate the operations of the root-hairs. These portions, too, by virtue of the vascular system which becomes developed in them, provide means of transport of the water, and its nutritive contents, from the absorptive hairs to the portions of the plant where they are needed.

Water is not permitted to stagnate in the tissues of a plant. If it is to be of use, it must circulate, and

bear its precious nutritive burden to the protoplasts, so that their demands may be met, and their chemical activities may be successful. It is well known that the aerial part of a plant gives off a good deal of water vapour. We can show this by covering a growing plant with a bell-glass, which will become clouded by the condensation of the water vapour. In some instances water is actually exuded, but the great bulk of water given off by plants passes out as water vapour. The water which is given off by a plant is replaced from the soil by means of the absorptive root-hairs. Evaporation and replacement naturally bring about circulation, and the process is denominated transpiration. The vapour escapes through stomata, and perhaps to a very minor extent through the cuticle. In typical land plants transpiration through stomata is very pronounced, and cuticular transpiration is negligible, yet the latter takes place to a marked extent in plants which flourish in damp places. Seeing that stomata are exits for water vapour, it is not remarkable that in normal land plants they are exceedingly numerous on the under sides of their leaves. In such a situation they cannot be inundated with rain-water, and so be prevented from playing their important part in transpiration. The openings of the stomata are regulated by "guard cells," which close the passages when evaporation is calculated to deplete the plant of its due meed of water, and open them when transpiration is essential. These guard cells perform this important duty quite automatically. When water is plentiful, they swell with turgidity, which so changes their size and form that the stomatal pores are opened to allow of the escape of water vapour;

Plate XLIII.

SELF-HEAL (*Prunella vulgaris*). Order *LABIATÆ*.

but when water is to be conserved they close the pores by loss of turgidity, and a corresponding alteration of form.

Continued excess of transpiration would, of course, be disastrous, and in such plants as those which live in deserts, or in high latitudes, the stock of water must needs be conserved. In desert conditions where there are long-continued droughts, such plants as can flourish there must take the fullest advantage of rain when it falls, and retain sufficient water to carry them over a drought; by no means must they permit an excess of transpiration. The Prickly Pears (*Opuntia*) and Cacti occur in great variety in the high plains of Mexico; they flourish in very dry sandy and stony places, and also in rock crevices where there is the smallest modicum of soil. For about nine months in the year no rain falls, yet the plants do not suffer and always appear "succulent." They are perfectly adapted to their environment. Their stem structure is remarkably developed; it is swollen, green, and interiorly fleshy, and it is responsible for carbon assimilation. The epidermis is thickened and almost cartilaginous, and in some instances oxalate of lime is deposited in great quantity so as to form a species of armour protecting the green tissue beneath the epidermis. Indeed the fleshy stem is a reservoir of water, the evaporation of which is prevented by the thickened epidermis and the mineral underclothing, and the store of water is sufficient to last the plant during the dry season. There are no foliage leaves; in their

FIG. 78.—SPECIES OF MELON CACTUS.

place we find hairs and dry scales. Very frequently the stems are protected from the ravages of thirsty animals by a complete armoury of spines. In high latitudes and on Alpine heights, where absorption of water is not possible for long periods because of the frozen ground, there is the same need for such plants as grow there to conserve their water-supply. They really flourish under conditions that are physiologically desert-like. Land plants that grow on the seashore must also avoid excessive transpiration. In their habitat it is frequently a case of "Water, water everywhere, nor any drop to drink," for they object to salt-water, and decline to absorb it, and depend upon such rain-water as they can obtain from ground which does not usually retain fresh-water in great quantity. Some such plants have met the peculiar conditions of their environment by developing succulent stems and leaves; the Sea-Rocket (*Cakile maritima*), Sea-Purslane (*Arenaria peploides*, Plate XLIV.), and Saltwort (*Salsola kali*) are examples. The Scentless Mayweed (*Matricaria inodora*), when it grows on the sea-coast, becomes quite fleshy, in striking contrast to its inland condition; the same phenomenon is observable in other land-plants growing under similar conditions.

The due regulation of transpiration in land-plants is of the utmost importance, and it is accomplished by various means. In some circumstances the process needs every encouragement, while in others it must be retarded. When plants grow in a humid atmosphere, transpiration is encouraged by enlargement of leaf-surface, which, of course, involves a vast increase in the number of stomata. Coltsfoot (*Tussilago*) and Butterbur

(*Petastites*, Plate XLV.) produce very large leaves when they grow in damp, shady sites, but not nearly so large when they are exposed to dry air and sunlight. Mention of Coltsfoot reminds us of the clothing of hairs on both surfaces of its young leaves, and on the under surface of those which are full-grown. In Britain, the young leaves appear early in the season, when they are subject to considerable variations in temperature and heavy rains; doubtless their hairy clothing serves not only to retain heat, but also to prevent the stomata from being choked by moisture, which would hinder the escape of water vapour. These young leaves are also inclined at an angle at which they can benefit most completely from the incident rays of sunlight, which promote transpiration and also encourage carbon-assimilation. The angle of inclination of the full-grown leaves is not so high, and as they attain their maximum growth in the height of summer, they do not then need to retain heat by a thick clothing of hairs on their upper surface, nor are the hairs needed to ward off moisture on that surface because there the stomata are few in number; but the under-surface is well furnished with stomata and thickly clad with hairs, the chief function of the latter evidently being to ward off dew, which we must remember really rises from the ground, and can as easily condense on the under as the upper surface of a leaf. The necessity for the hairy garb on the under surface of the Coltsfoot leaf becomes the more evident when we appreciate the fact that this plant grows in colonies whose leaves cover and shade considerable areas of ground, and the air beneath this leafy canopy is always humid, even on days of bright sunshine.

The development of succulent or fleshy leaves, as already noted in some plants which grow on the coast, leads to reduction of the evaporating surface, and so retards transpiration and conserves the water-supply. Such leaves enable the Stone-Crops (*Sedum*, Plate XLVI.) to grow in dry situations, such as on stone walls, old roofs, rockwork, and battlements. Similar leaves are developed by tropical Orchids, which grow on rocks or attached to the bark of trees.

Many plants, including shrubs and trees, extend their leaves parallel to the ground when they grow in shady places, but raise them vertically to the sun when they occur in a dry and sunny habitat. This distinction of leaf position has evident relation to transpiration. In the shady places the plants encourage the process by exposing greater leaf-surface, while in sunny, dry situations they retard it by exposing only the edges of the leaves to the incident rays of the sun. Kerner, in his *Natural History of Plants*, directs particular attention to the Silver Lime (*Tilia argentea*), a native of South Europe, in which on hot, dry summer days the leaves exposed to the sun assume a nearly vertical position, but any leaves of the same tree which happen to be shaded are extended horizontally. The *Eucalyptus*, in its early stages, when it is shaded by surrounding trees, produces unstalked horizontal leaves, thus promoting transpiration; but in its later growth, when it emerges from the shade, it bears stalked, narrow, long leaves, which hang from the branches with their edges to the strong light, in a position calculated to retard excessive transpiration.

Most, if not all, Grasses periodically fold and unfold their long linear leaves in relation to atmospheric con-

ditions in their successful efforts to regulate transpiration. Early in the morning the leaves are spread out flat, at hot noontide they are folded lengthwise, while in the evening they unfold, and become either flat or fluted. In the Marram Grass (*Psamma arenaria*), which grows on sand-dunes and needs to conserve water, the folding of the leaf in sunshine and in dry winds is particularly marked. The transpiring surface is folded inwards, and the living tissues are protected by layers of cells, with lignified walls which contain only air, as well as by a resistant epidermis on the exposed surface, all combining to form an excellent screen which restrains evaporation. If one picks a piece of the Common Hair-Moss (*Polytrichum commune*), which abounds in boggy places, and holds it for a short time in the hand, the leaves will be observed to close round the stem and clasp it. This is obviously a natural effort to conserve water by restraint of transpiration; the plant re-enacts speedily, under the abnormal circumstances, a movement which is habitual in a state of Nature when drought threatens. It gives us an exhibition, as it were, of "a ruling passion strong in death."

Very much more might be written in regard to a multitude of devices for the regulation of transpiration; indeed, we have touched but the fringe of the subject, and anything like an exhaustive treatment of it would demand a volume to itself. What has been said will suffice to draw attention to a most interesting study, which the reader may be disposed to follow out in greater detail.

On several occasions we have referred to water as a

transporting agent, as carrying nutrient salts in solution to those tiny chemists who reside in the tissues of plants, and are known as "protoplasts." Transpiration, we have seen, involves the circulation of these salts which go *into* the plant, and are there combined into compounds of an organic character, which promote growth. A green plant has the peculiar virtue of being able to convert inorganic into organic substances in a manner which is apt to bewilder the human chemist. It has been demonstrated that for the satisfactory nutrition of green plants ten elements are essential—these are carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, potassium, magnesium, and iron. It has also been shown that, in addition to these essential elements, silicon, chlorine, and sodium, are utilized. It seems that the necessary chemical elements are obtained from compounds, and cannot be used in an uncombined state. Thus, the carbon is taken from carbon dioxide in the atmosphere, and this gas is absorbed by the green parts of plants; the remaining nine essential elements are gained from various combinations, and absorbed by the root-hairs. Hydrogen and oxygen are got from water in the soil, water being a combination of these two gases; nitrogen is got from dissolved nitrates, sulphur from sulphates, phosphorus from phosphates, calcium and magnesium from carbonates, potassium from salts of potassium, and iron from salts of iron. We have elsewhere stated, in our notes on Bacteria (p. 13), that the free nitrogen of the air can be used by plants of the Pea family—*i.e.*, leguminous plants—through the good offices of certain Bacteria which reside in their roots; but this peculiar arrangement is exceptional, and in the great majority

PLATE XLIV.

SEA-PURSLANE (*Arenaria peploides*), ORDER *CARYOPHYLLACEÆ*.

Growing on shingly sea-beach.

of plants there exists no power of absorbing free nitrogen.

The solution of the various nutrient salts absorbed by root-hairs from the soil is very weak. Hence, in order that plants may secure the necessary quantity of salts they must take in much water, the excess of which passes off as water vapour in the progress of transpiration. True water-plants, which are wholly submerged, get all the nutrient salts and gases they require from the water, and in order that their demands may be satisfied it is usual for them to have finely divided leaves involving a sufficient absorptive surface. In some instances such plants have true roots, which, of course, add to the gain of nutrition effected by the leaves by drawing also upon the soil. Land-plants which have accommodated themselves to a partially aquatic environment, must not be confused with genuine aquatics.

It appears that in some instances, at any rate, root-hairs discharge an acid sap, which acts chemically upon minerals in the soil and makes them soluble, so that they may be absorbed. If a Bean be planted in an inch or so of soil laid over a piece of polished marble, and allowed to grow for six or seven weeks, on removing the marble it will be found that the acid sap has eaten into the polished surface, which will bear a tracing, or etching, of the roots.

In regard to the entrance of solutions into a plant by way of root-hairs or other cells, the word "absorption" is most apposite. Root-hairs are not open suction-tubes operating like the pipe of a pump; they are enclosed protoplasmic cells, and absorption takes place through their permeable walls of cellulose by *osmosis.*

This purely physical process is readily illustrated by a simple experiment. A glass tube is closed at one end by a piece of bladder, and partially filled with a solution of common salt; the closed end of the tube is now inserted in distilled water, and in due course the solution in the tube will be observed to rise. The salt in the tube has attracted the water, which has made its way into the tube through the permeable bladder. Absorption by root-hairs takes place on exactly the same principle. The cell-sap contains salts in solution and organic acids; it is denser than the solution contained in the soil, and attracts it even as the salt solution attracts the distilled water. The cell-wall is permeable, so the external weak solution is drawn through it to the inside of the cell, and it is passed on from cell to cell throughout the plant by repeated osmosis.

For some account of the great importance of carbon as a plant food, and the manner in which it is absorbed in the form of carbon dioxide by green plants, and assimilated with the assistance of chlorophyll, the reader is referred to p. 19. To recapitulate the story here would be a work of supererogation, but it must be borne fully in mind, otherwise the student will have a totally inadequate conception of plant nutrition.

In considering the physiology of plants it is further necessary to realize that, like animals, they breathe, the breathing process being termed "respiration." The process is certainly not so obvious in plants as it is in the higher animals, yet it most assuredly takes place. In breathing an animal takes in oxygen and exhales carbon dioxide as a product of internal combustion in

which heat is generated. The fact that green plants absorb carbon dioxide in sunlight, and in the process of carbon assimilation liberate oxygen as a waste product, is apt to obscure the equally important fact that they also, both by day and by night, take in oxygen and throw off carbon dioxide. The oxygen inhaled oxidizes tissues and liberates energy essential to the life of the plant, while the exhaled carbon dioxide is a by-product of tissue oxidization. We used to be told that to have plants in a room by night was dangerous to health, but that they were a source of health in daytime. The fiction was evidently based upon the idea that, because carbon dioxide is absorbed only in sunlight, it could be only in daytime that they could purify the atmosphere. True is it that carbon assimilation ceases at night, but it is equally true that oxygen is inhaled and carbon dioxide exhaled day and night throughout the life of a plant. It is not advisable in a book of this character to discuss the technicalities of plant respiration; they are somewhat abstruse, and the reader who is prepared to study them will refer to technical textbooks for such information as is available. It will suffice the ordinary reader to know that plants not only drink and eat, they also breathe.

So far in our inquiry into the nutrition of plants we have learned what elements are essential for healthy plant life, and the sources from whence these elements are obtained. We know the elements are present in chemical compounds, and are not absorbed in an uncombined state, and it has been plainly stated that the food absorbed in an inorganic form is transformed by the alchemy of protoplasts into organic compounds. It is

this alchemy which is rather bewildering to the human chemist, and it is vital to the existence of the flora and fauna of the whole world. But while our ignorance of the elaborate chemistry of plants is stupendous enough to keep us humble, we are not without some knowledge, which tends to increase, and we need not despair as to the results of present and future research. Setting aside theories and chemical formulæ, and all discussion of the method of vegetable chemistry concerning which the doctors may differ, we know that plants elaborate certain products which are easily recognized. First, there are nitrogenous, or nitrogen-containing, products; these are proteins and albuminoids. The proteins contain carbon, hydrogen, nitrogen, oxygen, and sulphur, and green plants elaborate them from water, carbon dioxide, nitrates, and sulphur compounds. Proteins are essential to the growth of both plants and animals, and the latter are dependent upon the supply manufactured by the former. Then, secondly, there are non-nitrogenous products, the fats and carbohydrates. The fats contain carbon, hydrogen, and oxygen; they may be derived from carbohydrates or result from the disintegration of proteins. Fats (or oils) abound in certain seeds, such as linseed, in nuts, and in such fruits as the Olive. Carbohydrates are compounds of carbon, hydrogen, and oxygen, in which the hydrogen and oxygen occur in the same proportions as in water (H_2O); they embrace sugar, starch, cellulose, and gum. Starch is an exceedingly important reserve material; it abounds in tubers, such as potatoes, and in starchy seeds—for example, rice, wheat, barley. Starch, being insoluble in water, is transformed into sugar, which is soluble,

Plate XLV.

BUTTERBUR (*Petasites vulg*

Order *COMPOSITÆ*.

when it needs to be translocated. Sugar seems to be the first product of the chemistry involved in carbon assimilation by the leaf under the influence of light, heat, and chlorophyll, and sugar is probably used by protoplasts in the manufacture of starch. The soluble sugar made in the leaves, in the first place, may probably be commandeered for immediate use in the leaf and elsewhere, while that in excess of immediate requirements may be converted into starch, and thus constitute a reserve. Possibly when reserve starch is drawn upon for nutriment its conversion into soluble sugar is accomplished by the agency of the ferment known as "diastase." Human indebtedness to plants that build up a starch reserve in cereal grains is beyond assessment. Cellulose is the most important constituent of cell-walls, and also occurs as a reserve substance, for instance, in the Date-stone, in which the cell-walls are greatly thickened and are dissolved in germination.

In addition to the products already named, and that may be considered as chief, there are others, due to plant alchemy, all of value to the plants in which they occur, and some of economic service to man. Among these are ethereal oils, resins, caoutchouc, hydrocyanic acid, tannin, malic, acetic, citric, and oxalic acids, and various alkaloids, including strychnine, morphine, caffeine, quinine, and cocaine. Indeed, the more completely we become acquainted with the organic compounds elaborated by plants, the more astounded are we at their variety and mystery. And in all our inquiries we cannot overlook the majesty and wonder of living protoplasm, the most marvellous substance in creation, which is capable of performing the most

remarkable feats of constructive chemistry—such feats, indeed, as stagger the ingenuity of man.

The growth of plants most certainly depends upon nutrition and the physiological activities involved therein. These may be regarded as the internal conditions of growth, but there are also certain external conditions affecting this life-process which need to be taken into account. Paramount among the external circumstances which stimulate and regulate internal activities are temperature, light, and gravitation.

Temperature has a most important bearing on growth. Plants cannot thrive at a temperature above 50° C. or below 0° C. The degree of warmth which promotes growth most successfully varies with different plants; it seems to rest between 22° and 37° C. Plants accustomed to life in high latitudes, in the Alps and polar regions, may exhibit vigorous growth at a temperature little above zero. It has been shown that the young roots of Wheat and Barley attain their maximum of growth at 22·8° C. A fall below this optimum temperature checks growth, and if the lower degree is maintained it will cause death. Death also ensues if the optimum of heat is exceeded to any considerable extent. The presence of moisture in plants has a bearing upon their death by exposure to extremes of temperature. Dry seeds can endure considerable extremes, such, indeed, as would speedily kill fleshy ones, or normally dry ones softened with moisture. The seasonal changes of temperature materially affects the growth of our perennial plants. In winter growth is suspended, in spring it is exceedingly vigorous, in summer it begins

ENGLISH STONECROP (*Sedum anglicum*), ORDER *CRASSULACEÆ*.

to abate, and in autumn it gradually declines to a minimum prior to entire arrest in winter.

We know that light has a most important chemical value for plant-life, that in its absence green plants cannot assimilate carbon; but it has also an influence which produces mechanical results, among which retardation of growth must be noted. All other conditions of growth being equal, it is certain that it is greater by night than by day. Plants which grow in feeble light are as a rule taller and have larger leaves than those of the same species that grow under conditions of intense illumination. Window plants exhibit a well-known mechanical result of one-sided illumination. They bend towards the light, and the curvature of the stems is due to retarded growth on the side facing the light, and the more rapid growth of the side which is not strongly illuminated. The bending of the stem has the happy result of inclining the leaves towards the light, so that it may exert its chemical influence to the fullest possible extent. Thus, assimilation proceeds at full speed by day, when growth is slow, and growth advances apace by night, when assimilation is arrested. Heliotropism (Gr. *helios*, the sun; *tropos*, a turn) is the term applied to the movements of plants in relation to light. The stalk which bends towards the light displays *positive* heliotropism, and the root, which seeks darkness rather than light, is *negatively* heliotropic.

Geotropism (Gr. *gē*, the earth; and *tropos*), or the natural tendency of the root to grow downwards and penetrate the earth, is at any rate in part due to gravity. The upward growth of the stem and the downward growth of the main axis of the root is in line with the

direction of the force of gravitation. The root is *positively* geotropic, while the stem exhibits *negative* geotropism. One is doubtful if the plain reader will consider this a sufficient answer to the question as to how it is that the root grows downwards and the stem upwards, and even were one to add the factor of "inherited experience" in plants, the sense of mystery might only be deepened. "Geotropism" certainly stands for something, but the use of a learned term does not necessarily imply a full explanation of phenomena in which *Life* is a more potent force than ordinary gravity.

Just here it is advisable for us to consider briefly, with the aid of some common examples, the strenuous way in which green plants may be said to affirm Goethe's demand for "Light, more light." The struggle for light and air is an important part of the silent warfare in which plants engage—a warfare waged relentlessly and without scruple. In this struggle it matters not to the combatant who fails so long as he succeeds. The Daisy on the lawn is a familiar and conspicuous example of a relentless plant warrior, a notable illustration of the Biblical principle, "A little one shall become a thousand, and a small one a strong nation." This plant increases as successfully in a vegetative manner as by the agency of seed. Its leaves are arranged in rosette form, their shape and arrangement being such that, without interfering with or shading others unduly, each one receives the maximum of light. But while the rosette receives all necessary light, it takes care that any grass attempting to grow beneath it shall get none at all; indeed, it literally suffocates the grass that

vainly endeavours to oust the invader. If we allow a single Daisy plant to have its own way on our lawn, it will speedily increase, and become an extensive colony, to the detriment of the grass. So successful will it become in its colonization, that wherever it grows it puts the grass out of action—an operation in which it is assisted by the lawn-mower, which by cutting the grass short prevents it from rising above and over-shadowing the enemy. The Dandelion and the Broad-leaved Plantain (*Plantago major*, Plate XLVII.) are also successful colonists of the lawn, and act on the same principle as that of the Daisy. The Primrose, which we all love for the beauty and delicacy of its flowers, and of which none are disposed to say an unkind word, nevertheless adopts a warlike attitude towards its competitors. It holds its territory by the asphyxiation of any invader with which it can by nature cope. The leaves, when they first appear, are folded, and they rise upwards towards the light. In due course they unfold, and after a time lay themselves flat, or almost flat, on the ground, spreading over a good area, and suffocating competitors beneath them. In the meantime fresh leaves spring up in succession from the centre. These, too, rise upwards at first, but in time spread outwards and reinforce the older leaves, some of which may have faded, thus maintaining the battle. The succession of new leaves is kept up during the vegetative period of the plant, and with each appearance of new leaves the older ones spread outwards until their turn arrives for outpost duty. The Primrose thus holds its ground in the righteous determination not only to occupy sufficient soil for its needs, but also to secure its just quota of

light and air. Where colonies of Coltsfoot or Butterbur subsist, there is little chance for would-be competitors. The large leaves of these plants place all beneath them in deep shade, taking light and air to themselves, and allowing none to plants which attempt to exist on the same ground. There is little wonder that, when the leaves of these successful warriors die down in late autumn or early winter, we discover the ground they had shaded to be almost clear of other vegetation.

The Daisy plant, when it grows among herbage which tends to overshadow it, and which it is not sufficiently powerful to suffocate, " draws up " to the light, and develops a larger leaf-surface. The Dandelion does likewise, its leaves becoming much longer, more delicate, and having a less indented margin than is the case when the plant grows in the open, where it suffocates competitors by laying its leaves flat on the ground. When the Dandelion, in adaptation to its habitat, grows as a flattened rosette, the leaves are deeply indented, which, of course, reduces the transpiring surface, and at the same time considerably reduces the possibility of one leaf taking light from another. In fact, the Daisy and Dandelion produce " leaf mosaics." A leaf mosaic is a close-pattern leaf arrangement in which each leaf is situated in such a relation to other leaves as not to intercept the light and atmosphere demanded by its fellows, and it is a common feature in the plant world. It is conspicuous in rosette forms, as already indicated, in the Ivy that creeps over the floor of a wood, or climbs up a tree-trunk, and in the leaves that are massed at the ends of Sycamore branches.

In relation to the need for light and air, plants have

GREATER PLANTAIN (*Plantago major*), ORDER *PLANTAGINACEÆ*.

become confirmed in many curious habits, and have adapted themselves to fill many niches. The Anemone (*Anemone nemorsa*) and the Lesser Celandine (*Ranunculus ficaria*) are common in some woods, and in early spring are exceedingly active, They make themselves busy while, for them, the sun shines—*i.e.*, before they are cast into deep shade under the leafy canopy of forest-trees. In point, they conclude the principal business of their season while the trees are yet in bud, and thus do not intercept the light to anything like the extent they do when in full foliage. The leaves produced by the Celandine after its flowering period, particularly in shade, are much larger than those which at first appear, and it is evident that this enlargement has relation to the necessity for a larger assimilating and transpiring surface in shade conditions. The Marsh Marigold (*Caltha palustris*, Plate VIII.), as its name implies, grows in damp places, generally in full light of the sun. It flowers early in the year, and at the time of flowering its leaves are not nearly so large as they become when the flowers have done their work. It is certainly an advantage for the flowers not to be overshadowed by leaves, as they might be were the latter to reach full growth at the flowering time; but the post-flowering leaf enlargement has definite relation to assimilation and transpiration, which are very seriously undertaken after the flowers have served their use. A plant that grows, like the Marsh Marigold, with its feet in the water, so to speak, or at any rate in very damp sites, can support a large transpiration area, even in full sunlight. One might say that the Marsh Marigold, like numerous other plants, devotes its spring energies to flowering, and its

subsequent efforts to the manufacture and storage of reserves in advance of the next season's demands.

The Lesser Periwinkle (*Vinca minor*) has tough trailing stems bearing evergreen leaves. It finds its niche on the floors of woods, where in shade conditions it competes successfully with other plants by covering the site it occupies with its many-leaved trailers. Its leaves are not large, but they are evergreen, and they make up for deficiency in size by their quantity and lengthy period of activity. Thus, the plant is able to fill its niche in the shade by peculiar adaptation to the lighting conditions.

Such plants as the Dog Rose (*Rosa canina*, Plate XLVIII.) and Bramble (*Rubus*) have been well classed by Charles Darwin as "Scramblers," for they literally scramble in the direction of the light, using other plants for support with utter disregard for their requirements. They hang on to their supports by means of recurved hooks, produced from stems and leaves, and how thoroughly they are served in this way is realized by anyone who has seriously attempted to disengage either of these scramblers from a hedgerow. The scrambling stem of a Bramble plant may, under suitable circumstances, attain very considerable length. I recently took careful measurement of a stem issuing from a plant rooted on the outskirt of a wood. The site of the root was in deep shade, and the stem to which I refer scrambled along 10 feet of ground to a hedge, and over the hedge, which was not less than 10 feet high, into bright light. The total length of this stem was 50 feet. The Goosegrass (*Galium aparine*), known to Scotsmen as "Sticky Willie," is furnished with almost innumerable hooked

DOG ROSE (*Rosa canina*).

1. Fruit 2. Cross section, fruit 3. Section, flower

bristles, by which the plant clings to supports. It is an exceedingly common denizen of hedgerows, and a most vigorous scrambler. It should be remarked that a peculiar plant device may possibly serve more than one purpose. The hooks of the Bramble, for example, not only ensure a place in the sun for the leaves, but also a conspicuous display of the flowers and fruit. This display has relation to insect pollination and the scattering of seeds by the agency of birds.

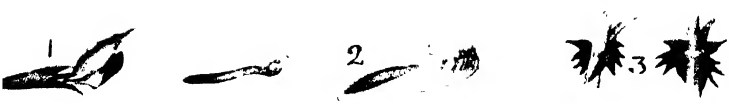
Mention must also be made of the twining plants, which twine round other plants, and thus use them as supports in their lightward progress. Members of the Convolvulus family are familiar examples, as also are the Hop (*Humulus lupulus*), the Honeysuckle (*Lonicera*), and the Black Bryony (*Tamus communis*). The Hop produces T-shaped hairs, which are quite stiff, and evidently assist in making good the progress of this twiner.

Other plants have developed tendrils which during their growth are very sensitive to contact, and when they come into touch with a support, they rapidly twine around it. Thus, stems which are too weak to support themselves in an upright position are able to be drawn upwards to light and air. The tendrils may be modified leaves, stem structures, or roots. In the Vine they are modified floral branches, as is also the case in the Passion Flower (*Passiflora*). In the Vetches (*Vicia*, Plate XLIX.) and the Peas (*Lathyrus*) the terminal leaflets are replaced by tendrils, and in their case the tendrils may be regarded as modified leaflets. The *Clematis* grasps a support by means of its leaf-stalks (petioles), which are very sensitive to contact, and twine round a support

when they come into touch with it. The Virginia Creeper (*Ampelopsis*), so frequently grown to beautify bare walls, has small pads at the ends of tendrils. These pads are adhesive, and enable the plant to hold on to a surface which it could not grip without their assistance.

The Common Ivy (*Hedera Helix*) is classed as a root-climber. In its efforts to reach light and air it produces adventitious clasping rootlets from its branches, and these are used by the plant in clinging to trees, walls, or other supports. These rootlets are simple holdfasts, making possible and successful the quest upon which the Ivy is engaged. It proceeds "line upon line, and precept upon precept," making sure of secure support on every step of its lightward journey. These familiar rootlets, then, are purely for climbing purposes. They do not absorb nourishment, nor do they insert sap-sucking processes into a supporting tree. It is common among persons unversed in botany to call the Ivy a parasite, but such it is not, although it may suffocate a tree. Determined to thrive at all costs, it seeks a support. It has no compunction in making a tree into a ladder, and if the tree be suffocated, what does the Ivy care!

The gloom of the dense tropical forest has to be experienced to be appreciated. The trees intercept light, and cast the interior and the floor into deep shade. There is little wonder that climbing plants, particularly those with twisted woody stems, known as "lianes," are common in these forests. These plants sprawl over undergrowth until they reach trees, up which they climb in their effort to reach the light. Their twisted ropelike stems on the floor are a serious



COMMON VETCH (*Vicia sativa*),
Order *LEGUMINOSÆ*.

1 Flower, side view 2 Essential organs
3. Stipule, from above and from below

obstacle to travellers. While lianes are most abundant in the tropics, they are not entirely confined to those regions. They occur in Chili and New Zealand, and even in Britain we have three species—the Honeysuckle, Clematis, and Ivy. It was particularly to the lianes that the poet Domett referred when he wrote these lines:

> "Exulting Nature so delights,
> So riots in profusion, she
> Twice over does her work for glee!
> A tangled intricacy first she weaves,
> Under and upper growth of bush and tree
> In rampant wrestle for ascendancy.
>
> * * * *
>
> There mounting to the tree-tops, down again
> Comes wildly wantoning in a perfect rain
> Of trailers—self-encircling living strings
> Unravellable; see how all about
> The hundred-stranded creeper cordage swings!"

Plants which grow attached to the elevated parts of other plants, firmly held in position by clasping roots, or by other means, but drawing no nourishment from their supports, are called Epiphytes (Gr. *epi*, upon; *phyton*, a plant). They must not be confused with parasites. In Britain, the epiphytes are represented chiefly by lichens, mosses, liverworts, and ferns, and sometimes we may see some such phenomenon as an Ash growing in the hollow of an Oak; but the true epiphyte is specially adapted for the site it occupies. It has arrangements for water-storage, or special means of water-absorption, and it is also protected against excessive transpiration. Besides, it has adopted particular means of seed-dispersal. Its seeds must be very light,

or enclosed in a sticky fruit—in the former case in order that they may be dispersed by the gentlest breeze, or in the latter that they may be carried by birds and deposited on the branches of trees. Many Orchids are epiphytic. The higher epiphytes are best developed and most abundant in the tropics. The position taken up by epiphytes has evident relation to the demand for light, and their devices for conserving water are essential for successful growth on the bark of a tree. It should be added that epiphytes will grow in soil if the lighting conditions are suitable.

But the light demanded by plants must be just enough, and not too much. A too great light intensity may be just as deleterious as an insufficient illumination is disastrous. The positions assumed by leaves to avoid excessive transpiration (p. 266) may also serve to prevent the injury resultant upon too full an exposure to strong light. The Ferns which flourish in the shade of rocks or on the floor of a wood are so well adapted to their situations in relation to light that if they are subjected to intenser light by the removal of the objects which give them shade they lose their vigour, and become pale and sickly. So is it with such a plant as the Woodruff (*Asperula odorata*, Plate L.). This flourishes well in shade, particularly that of a wood, but if the woodcutter clears the overgrowth, and admits strong light, the plant speedily deteriorates. Kerner, in his *Natural History of Plants*, draws particular attention to the flora of the broad ridges and terraces of the rocky shores of the Mediterranean, where the plants are exposed to full light during the whole of their vegetative period. They are "shrouded in dull grey, clothed in silk or wool,

PLATE L.

WOODRUFF (*Asperula odorata*). ORDER *RUBIACEÆ*.

or else overstrewn with chafflike scales." Their outward garb covers and protects the chloroplasts, and serves as a light screen. It has also been shown that in the leaves of many green plants, when it is desirable to make the most of the light, the chloroplasts assume a rounded or perhaps conical shape, and project towards the centre of the cells, thus intercepting all light possible; but when the light is too intense, these colour-bodies become flattened, and withdraw from the centre to some extent, thus avoiding the excess of light.

Having given some attention to the relation of green plants to light, and shown that the methods adopted and the positions assumed bear principally upon carbon assimilation, we must now devote a little space to some notes on plant peculiarities in respect to nutrition. In this regard plants are classified as Green Plants, Carnivorous Plants, Symbiotic Plants, and the non-green Saprophytes and Parasites.

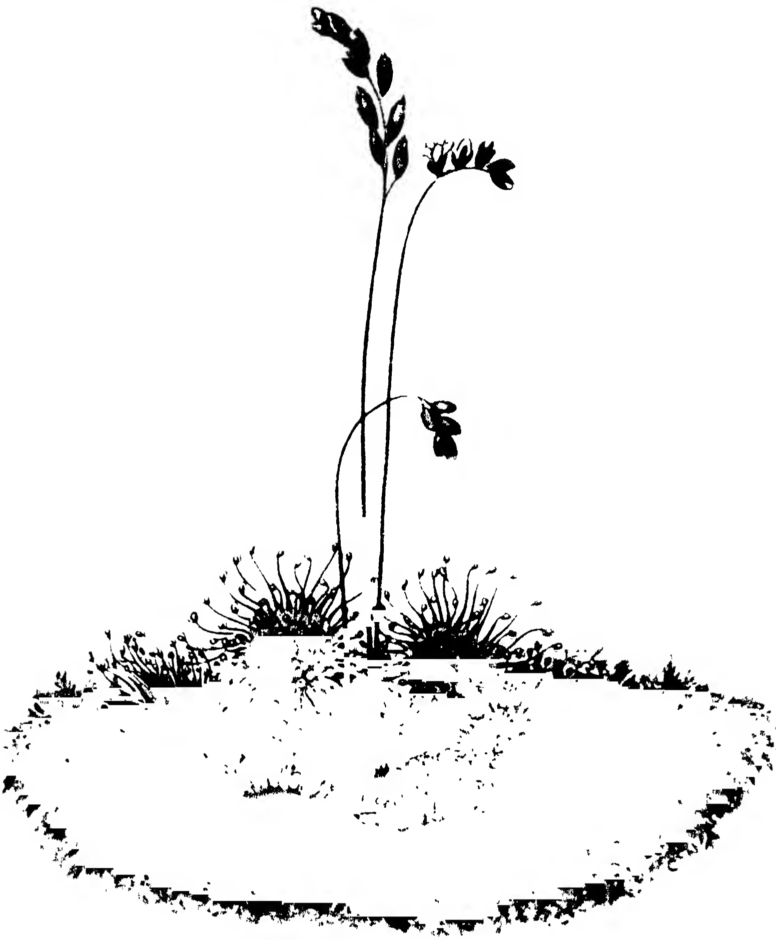
From what has already been stated, the reader will have concluded that Green Plants, whether they be land forms or aquatics, are self-nourishing. They labour for their living in a self-respecting manner, and with commendable industry. This statement has reference to normal forms, and is not applicable to some green hemi-parasites which seem to have embarked upon a vicious career.

The Carnivorous Plants, or Vegetable Flesh-consumers, have a peculiar interest, and are remarkable instances of the manner in which plant life, face to face with great difficulties, has most ingeniously adapted itself to the demands of a situation, and come out vic-

torious. About 500 species of Carnivorous plants have been distinguished. They have been driven to extremities, and compelled by their situation to adopt unusual feeding habits. It may be said of them in general that they exist under conditions where nitrates are commandeered by other plants, or are not present in sufficient quantity for their own health. Nitrogen, we know, is essential to plants. Without it they cannot build up proteins. The Carnivorous Plants have arrangements for the capture and digestion, in one way or another, of animals, from which they extract the nitrogenous materials essential to their existence. The usual rule is to capture, say, an insect, then treat it with a digestive fluid, the resultant broth being finally absorbed by osmosis (p. 269) by cells through their cell-walls.

FIG. 79.—PITCHER OF PITCHER-PLANT (NEPENTHES DISTILLATORIA).

There are over thirty species of Pitcher Plants, found in the tropics, which have assumed the carnivorous habit. We take for description the species *Nepenthes distillatoria* (Fig. 79). This plant thrives on marshy ground bordering pools which are to be found in the damp primeval forests of the tropics. In its infancy it seems innocent of designs on the insect fraternity. But the early seed-leaves are succeeded by a rosette of leaves which have a suspicious look. These leaves rest in part upon the mud, but they curve upwards so that the greater part of their surface is clear of the mud. Each leaf



ROUND-LEAVED SUN-DEW (*Drosera rotundifolia*) ON SPHAGNUM MOSS,
Order *DROSERACEÆ*.

A carnivoro

develops at its end a scale curiously like a cock's comb, and this covers a slitlike opening in the enlarged leaf-stalk, and this opening is defended on both margins by an arrangement of rough points. This, however, is an early stage of growth. By-and-by stems grow out of the rosettes, and send forth leaves which are among the great wonders of nature. These leaves develop in this way: First, there appears a petiole, or leaf-stalk, flattened and winged, shaped after the fashion of a lance drawn to a long point. The point gradually lengthens until it becomes a long tendril, reaching out to the branch of a near-by tree. Round that branch the tendril coils snakelike, making it a support by which the plant can climb, and also from which it can hang its advertisement and death-trap. In the end this coiling, snakelike petiole is enlarged at its extremity until it assumes the appearance of a pitcher surmounted by a lid. The pitcher is thus the hollow enlarged termination of the leaf-stalk; its lid is a diminutive leaf-blade, highly modified. The plant produces numerous leaves of this description; it uses other plants, dead or alive, as supports, and so is able to display its gaily coloured pendulous pitchers to great advantage. In colour alone the pitcher is attractive to insects, but it renders its attraction tenfold by discharging honey round the rim and on the under side of the lid. Insects are lured by the honey bait, and, in attempting to satisfy their lust for sweet things, are apt to fall into the "pitcher." Once there they cannot readily escape. The inner surface of the pitcher is coated with wax, smooth and slippery, and at the bottom of the vessel there is a quantity of water in which captured insects

are drowned. In some species of *Nepenthes* the inner margin of the rim is armed with teeth pointing inwards and downwards; these teeth present a barrier impassable by any victim which has succeeded in freeing itself so far. The water in the pitcher is at first slightly acidulated by means of a secretion from special glands, but when insects are captured the secretion is greatly stimulated, and a digestive fluid is added. The insects are thus macerated, and their digestible parts enter into the composition of a broth, which seems to be absorbed by special cells situated in the lining of the bottom of the pitcher.

The Droseraceæ form a family of carnivorous plants. There are, in the world, six genera and about 110 species; they grow in sandy or marshy places. In Britain the family is represented by three species, all of the genus *Drosera*, of which *D. rotundifolia*, the Round-leaved Sundew, is the commonest and best known. The characteristic features of this species are portrayed on Plate LI. The leaves are arranged in a rosette, 3 or 4 inches in diameter; they lie pressed to the ground, or with a slight inclination upwards. On their upper surface they are furnished with reddish, knobbed glandular hairs, which may be described as " tentacles." The glands secrete tiny drops of a viscid fluid, which glitter in the sunshine and form an attraction to small insects. Hapless insects that settle on the leaves in hope of securing a sweet morsel are speedily and fatally undeceived. The sticky secretion traps them, and the more they struggle to escape the more inextricable is their position. The glands to which the insect adheres bend inwards with their burden, and in time all the

PLATE LII.

COMMON BUTTERWORT (*Pinguicula*
ORDER *LENTIBULARIACEÆ*.

A carnivorous

other glands bend in the direction of the captive, as if by common consent, and it is soon held in a sort of octopus grip. Once the glands have secured a firm hold and taken up their intended position, they secrete an acid juice in the first place, and afterwards pump a digestive ferment upon the insect. This ferment dissolves the nitrogenous matter of the captive, and reduces it to a liquid which can be absorbed by the cells of the leaf. Small flies, such as gnats, are digested in about two days. The indigestible parts of the victim become dry, and as the tentacles are dry for a time after digesting their prey, the wind acts as scavenger, removing the remains.

The Venus's Fly-trap (*Dionæa muscipula*) belongs to the Droseraceæ; it occurs in peat-bogs in the east of North America, in a strip of country extending from Florida to Long Island. As in *Drosera*, the leaves form a rosette. Each leaf consists, first, of a flattened petiole which is truncated to the fore, and there contracted to the midrib, and, second, of a rounded blade, the two halves of which are, as it were, hinged. The margins of the blade are fringed with rather long pointed teeth, and on the central area of each half of the surface there are three stiff bristles, which are very irritable. Owing to the irritability of these bristles, an insect coming in contact with them is entrapped by the sudden closing together of the two halves of the blade; they close up like the leaves of a book. When the captive has succumbed it is treated with a digestive ferment, secreted by glandular hairs situated on the surface of the blade, and the liquid product is absorbed and assimilated by the plant.

The Butterworts (*Pinguicula*) are also carnivorous. About twenty species are known; they occur in north temperate regions. We have three British species, *P. vulgaris* (Plate LII.) being particularly common in boggy places. The generic name is from *pinguis*, fat, and has reference to the greasy texture of the pale green leaves. This plant does not have tentacular leaves, but their surface is sticky, and small flies, which seem to be attracted by them, are captured by a species of " bird-lime " trick. The margins of the leaves roll over a captive, and certain glands secrete a digestive ferment. The leaf forms a sort of bowl, with a recurved rim, in which the insect broth is retained until it is completely absorbed. In Lapland the leaves are used to curdle milk.

The Bladderworts belong to the same family as the Butterworts (*Lentibulariaceæ*), but are classed in a separate genus, *Utricularia*. There are about 150 species, some of which are terrestrial. The aquatic species known in Britain, three in number, are floating plants with much divided leaves, the segments being very slender. The name " Bladderwort " is due to the existence of so-called " bladders " among the leaves. These bladders used to be regarded as floats, but investigation has proved that they are minute traps in which small water animalculæ, such as Cyclops, or Water-fleas (*Daphnia*), are captured. The captives are not treated with a digestive secretion, but are allowed to die in the natural course, and the liquid product of their decay is absorbed by glands that line the inner surface of each bladder.

Symbiotic plants (Gr. *syn*, together; *bios*, life) are

instances of vegetable partnership and messmatism, in which two different plants live together to their mutual advantage, particularly in relation to nutrition. Lichens are remarkable examples of this partnership, but as we have already considered them to some extent (p. 112) there is no need to describe them in this place. We have also referred to the Bacteria in the root-nodules of leguminous plants (p. 13)—another instance of symbiosis. Perhaps even more remarkable than these plant partnerships are those which have been noted between plants and animals. There is the case of the rotifer and the Liverwort, *Frullania dilatata* (p. 131). Minute green Algæ thrive in the body of the fresh-water *Hydra viridis*. Certain moths lay eggs in the carpels of *Yucca*, and the larvæ which emerge from the eggs feed on the seeds of the plant; but the seeds would not mature, and consequently the larvæ would perish did not the moths carry pollen from anthers and literally force it into orifices in the stigmas. The moths thus enable the *Yucca* to ripen fruit, and the plant in return for the service does not grudge the larvæ a modicum of seed as food. The naturalist Belt was the first to call attention to the Bull's-horn Acacia (*Acacia cornigera*). The stipules of this plant have been modified into hollow thorns, in which certain warrior ants reside. The tree provides the ants with food, and the ants in return defend the tree against the incursions of leaf-cutting ants, which threaten dire damage. This association between plants and ants is called "myrmecophily," from the Greek *myrmex*, ant.

Saprophytes, numerous among the Bacteria and Fungi (see pp. 13 and 99), derive their carbohydrates,

which in the absence of chlorophyll they cannot make for themselves, from decaying animal or vegetable remains; thus they are useful scavengers, as they assist very materially in reducing noxious matter to humus, and in rendering it serviceable to the lives of green plants. Saprophytes probably make most of their own proteins, but they may absorb any that are available. Among the higher flowering plants there are a number which have become total saprophytes, probably owing to their having fallen into the habit of making use of a subject fungus known as a "mycorhiza." This subject fungus takes the place of root-hairs; it is in intimate association with root or stem, and absorbs decay products in humus, and passes them on to the plant, which holds it as a vassal. Here, indeed, we have a turning of the tables. The fungus, which we might expect to batten on a higher plant, is actually commandeered into its service. British saprophytes of the flowering type are few. We have the Bird's-nest Orchid (*Neottia Nidus-avis*), which is leafless; its stem is pale brown, and its flowers, arranged in a spike, are dingy brown. It is found in many parts of England and Ireland, also in Southern and Central Scotland, in the humus of damp woods, but it is not common. The Coral-root Orchis (*Corallorhiza innata*) is very rare; it has a repeatedly branched rhizome, resembling branched coral, hence the name. There is no true root. The leaves are reduced to mere scales; the stem and flowers are a greenish yellow. The plant is found only in the East of Scotland, in moist woods. The Yellow Bird's-nest (*Monotropa hypopitys*) belongs to the Heath Family, Ericaceæ. It occurs in the humus of Birch, Beech, and Fir woods

PLATE LIII.

TOOTHWORT (*Lathræa squamaria*),
ORDER *OROBANCHACEÆ*.

A parasitic plant.

1. Calyx
2. Corolla
3. Flower
4. Petal and pistil
5. Cross section, ovary

Total parasites derive all their food from the host-plants upon which they batten. The Toothwort (*Lathrea squamaria*, Plate LIII.), doubtless descended from honest ancestors, has lost all nobility; it takes all its food from the roots of trees, particularly Hazels, Poplars, and Beeches. The Broomrapes (*Orobanche*) are also total parasites. There are nine British species, which draw nourishment from roots of Clover, Ivy, and other plants. The Dodders, of which Britain has only two native species, *Cuscuta Europœa* and *C. epithymum*, belong to the Convolvulus family. We may conclude that they were originally honest twining plants, which, however, departed from virtue by inserting suckers into their living supports at points of contact, and thus extracting nutrient material. They gradually descended in the scale of honour by depending more and more upon their hosts and doing less and less of honest labour, until at length they became "hangers on" of the most vicious type. The Dodder battens on several plants, such as Hawthorn, Gorse, and Wood-sage. Once established on a Clover crop, *Cuscuta trifolii*, a variety of *C. epithymum*, can do great damage, as a single plant has been known to devastate no less than thirty square yards of Clover in the course of three months. A thread-like embryo is coiled up in the seed. On emergence therefrom, in germination, it holds on to the ground by one end, and the rapidly growing filament above ground attaches itself to a host-plant, coiling round it in the manner of a tendril. Should it fail to come in contact with a host it must perish, as it is so degraded that it cannot manufacture food for itself. At points of contact with the stem of the host the parasite inserts suckers,

which penetrate to, and tap sap in, the vascular bundles. It is now established and on the strength of another's labour it branches and extends with astonishing rapidity, grasping other hosts in the neighbourhood, and extracting food with ignoble industry. Fortunately the Dodder is an annual; its cycle of existence is completed in a single season, but it develops a large number of flowers and an abundance of seeds, which perpetuate its kind. Agriculturalists are apprehensive of the Dodder, and if they are wise wage relentless war against it.

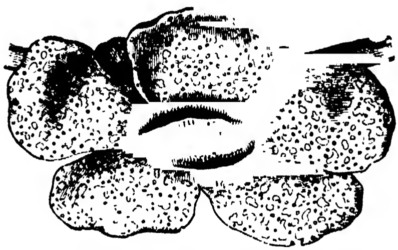


Fig. 80.—The Parasite Rafflesia arnoldi.

The student of flowering parasites will observe that, in consequence of the parasitic habit, involving the loss of ability to manufacture food in the normal way of green plants, there is a great reduction of leaves. In the Dodder all that is left to indicate ancestral foliage is seen in very small yellowish scales. In some species the stems also are much reduced, while in the tropical *Rafflesias* the flower is practically the whole plant. *Rafflesia Arnoldi* (Fig. 80) is the largest known flower; it is over a yard across. It grows in Sumatra. Quite stemless, it rests immediately upon roots of species of *Cissus,* from which it extracts the nutriment necessary for its giant form. The rapid growth of some parasites, and their prodigality in reproduction, remind one that "ill weeds grow apace" —an adage which the reader will agree is applicable to other than parasites of the vegetable kingdom.

CHAPTER X

THE PERPETUATION OF THE RACE

In order to perpetuate the race, plants, like animals, multiply and replenish the earth. This fact, obvious enough to the observer, is one upon which we have remarked in several places, and we have described both asexual and sexual modes of propagation. If it has not been stated in so many words, it has at least been implied that reproduction is primarily the result of growth. To what has already been written on the subject, we have now to add a few notes—first, on what is termed "vegetative reproduction"; second, on modes of pollination; and, third, on methods of seed dispersal leading to more or less successful colonization of new territory.

Vegetative reproduction in unicellular plants takes place by repeated divisions, as in the Bacteria, a method of propagation equally as common in unicellular animals. In the aquatic Algæ of the multicellular types, pieces of a plant may break away and develop into separate individuals identical with the parent plant, or they may produce ciliated zoospores, which eventually come to rest, withdraw their cilia, and give rise to a plant form similar to that which produced them. No operation of sex is involved in the production of zoospores; they are a mode of vegetative reproduction. But they are

BISHOP-WEED (*Ægopodium Podagraria*), ORDER *UMBELLIFERÆ.*

valueless in any but an aquatic environment. Liverworts and Mosses, which we take as instances of the humbler land-plants, propagate as freely by vegetative means as by the sexual mode. In them the aquatic zoospore seems to be replaced by detachable buds, or gemmæ, which readily develop into new individuals.

In the animal kingdom asexual reproduction, and also regeneration of lost parts, are observed up to a certain point. The fresh-water Hydra may be cut up into quite a number of pieces, and each piece may reproduce the parent form, and it is commonly known that this animal produces buds which remain vitally attached to the parent even after they are so far grown as to be able to fend for themselves. Ultimately, however, they become detached. Asexual reproduction is found from the simplest animal forms up to the Sea-Squirts, or Tunicates. Regeneration of lost parts, which, of course, does not imply multiplication, is well illustrated by Crabs and Starfish; it also occurs in Lizards. Any of these animals can regenerate a lost limb with a facility which must be the envy of a man who has had an arm or a leg amputated. Man and the higher animals have lost a power of physical regeneration possessed by humbler creatures; it is the price they have to pay for complex organization. Yet even highly organized man is not entirely destitute of regenerative capacity, for he can replace a portion of skin or a finger-nail that he may have lost. But if the capacity for reproduction of complete individuals from parts of a parent form is arrested at a certain point in the scale of animal life, it is hardly so in plants. The capacity is exhibited, in a great variety of ways, almost throughout the entire plant

world. There are instances in which it is lacking, notably in some Palms and Conifers, but in relation to the whole these exceptions are few. It is well known that horticulturalists take the fullest advantage of the capacity, for they regularly propagate plants by means of slips, cuttings, runners, tubers, corms, bulbs, suckers, buds, etc. The *Begonia* is frequently quoted as a notable instance of reproductive possibilities. If a leaf of this plant has slits made across its veins, and it be pegged down to soil, buds will in due course appear, and develop into ordinary plants.

In the higher plants vegetative reproduction occurs in various modes. New individuals may arise from rhizomes, or underground stems, as in the Iris, Coltsfoot, Mint, Couch-Grass, and other plants. Such a plant as the Coltsfoot is extremely difficult to eradicate from ground it has determined to occupy. In winter its underground stems are, of course, hidden from view, and because of the decay of the foliage above ground the existence of so great a subterranean potentiality is not known. The gardener may dig up the stems, but they readily break, and any portions with buds left in the ground will give rise to new plants. Mint is equally difficult to deal with, and as to Bishop-Weed (*Ægopodium Podagraria*, Plate LIV.), an umbelliferous plant, words fail to express the detestation in which the pestilential weed is held by gardeners. Its underground runners ramify in all directions, the strongest of them penetrating to a depth at which they avoid the spade; a small piece of a runner left in the ground may produce a big colony. Dog's-Mercury (*Mercurialis perennis*) and the Stinging-Nettle (*Urtica dioica*) owe the greater part

HOUSELEEK (*Sempervivum tectorum*),
ORDER *CRASSULACEÆ*.

2. Inner stamen with ovules.

of their success in colonization to their capacity for vegetative reproduction by buds arising from their underground stems.

To what are commonly called "runners"—that is, prostrate shoots given off by a plant, which lie on the ground and root—the name "stolons" (Lat. *stolo*, a twig) has been given. Stolons give rise to new plants at points where they root. We have a good example of them in the Strawberry. Plants are also reproduced by "suckers." These are underground branches which have turned upwards in quest of light and air, as instanced by the Raspberry and the Rose. Suckers also grow from buds developed on roots. This happens commonly in some fruit-trees, also in the Elm and Lilac. In the House-Leek (*Sempervivum tectorum*, Plate LV.), vegetative reproduction takes place by the formation of short stolons in the axils of the outer leaves of the rosette, and these stolons produce new plants, which root, and are ultimately separated from the parent plant. The phenomenon is illustrated in the plate referred to. The Ground Ivy (Plate LVI.) is an instance of a plant with a prostrate stem. Both the stem and the shoots arising from it creep along the ground, and root at their nodes. The original plant dies, but the rooted branches, separated by its death, live on, and perpetuate the species.

Bulbs and Corms are also means of vegetative reproduction. A bulb consists of a series of underground leaves, swollen, fleshy, and replete with reserve nutriment—Examples, Tulip and Narcissus. A corm is a swollen stem, also full of food reserves. It is typically developed in the Crocus. A Potato is a tuber packed

with food reserves. Each " eye " indicates a bud, which under favourable circumstances will develop into a new plant. This plant, by means of its tubers, has a remarkable capacity for vegetative reproduction, which the gardener is not slow to recognize and profit by. The Dahlia of cultivation, in order to provide for the next season, and pass successfully through a resting stage, packs plentiful reserves in some of its roots, which consequently become tuberous. From the tuberous roots new plants emerge. The Lesser Celandine (*Ranunculus ficaria*), bearing yellow, buttercup-like flowers early in the season, when it grows in shady places, seldom ripens fruit, but it thrives vegetatively not only by underground tubers, but also by means of tuberous buds, known as bulbils, produced aerially in the axils of the leaves. These bulbils are liberated when the plant withers, and, falling to the ground, develop into new individuals.

The Canadian Water-Weed (*Anacharis alsinastrum*) has been introduced into Britain, and since its first discovery there about the year 1842 has become almost ubiquitous in our ponds and streams. Yet it is not known to produce seed in this country. Its stem is very brittle, and any portion of it furnished with a few leaves is capable of rooting, or even growing in a free floating state. It is a remarkable instance of an introduced plant extending tremendously in a short period by purely vegetative means.

Some aquatic plants avoid being caught in the toils of ice in winter-time by sinking to the bottom of the water, where the ice does not reach, and where they can enter upon a period of rest with a good degree of

impunity. This is the case with the Water Starwort (*Callitriche*) and the Water Soldier (*Stratiotes aloides*). On the approach of genial conditions, they resume activity at the surface. But other aquatics in late autumn produce short leafy shoots, which detach themselves from the parent plant, and sink to the bottom of the water, where they root in the mud. They rest during the cold season, but in spring grow vigorously. The Curled Pondweed (*Potamogeton crispus*) is a common instance of this mode of hibernation and vegetative reproduction.

Little plants destined to attain full growth frequently grow from the radical leaves of the Ladies' Smock (*Cardamine pratensis*, Plate XXIV.) when that plant thrives in wet ground. Another excellent instance of the power of a leaf, while still growing on the parent plant, to produce plantlets occurs in a Fern much favoured by cultivators—*Asplenium Fabianum.* These plantlets are a most successful means of propagation. In some grasses which grow at Alpine elevations, notably the Alpine Meadow-Grass (*Poa alpina*) and the Sheep's Fescue-Grass (*Festuca ovina*), plantlets are developed in place of flowers, and these eventually become detached and take root.

Sexual reproduction dependent upon the fertilization of the egg-cell by a male element has been fairly fully considered in previous chapters, both in relation to cryptogamic and Flowering plants. It remains for us to make a pointed statement as to how in the latter pollen may be successfully transferred from anthers to stigmas as a vital preliminary to fertilization. This transfer is

called "pollination." We shall see how water, wind, insects, and even birds, are drawn into the service of plants in this regard.

A remarkable feature of Flowering plants is the number and variety of ingenious devices that have been elaborated to ensure cross-fertilization—that is, that the male element of one flower shall only fertilize the egg cell of another flower. The different flowers may occur on the same plant, but for obvious reasons cross-fertilization, if it has advantages, is calculated to produce them to the fullest extent only when the union is secured between the sexual cells of totally distinct plants. So notable are the devices that ensure cross-fertilization in many Flowering plants that students of the phenomena at one time rushed to the conclusion that self-fertilization was an actual evil. But that notion is now undergoing revision. That cross-fertilization has its own advantages will not be denied, but they are not easy to define. On the other hand, it is not demonstrable that self-fertilization in flowers, where it occurs, has any harmful effect on their posterity; indeed, some of the most widespread and vigorous weeds, including such well-known species as the Shepherd's-Purse (*Capsella Bursa-pastoris*), the Groundsel (*Senecio vulgaris*), and Chickweed (*Stellaria media*), are self-fertilized. It is obvious that self-fertilization can take place only in hermaphrodite flowers—that is, in those which include in the same flower both male and female organs. The great Linnæus tumbled to the conclusion that hermaphrodite flowers were invariably self-fertilized. He evidently had not time to observe the varied devices in such flowers for the avoidance of self-fertilization. We

GROUND IVY (*Nepeta*

ORDER *LABIATÆ*

now know that cross-fertilization is exceedingly common among hermaphrodites, but we have also learned that, wonderful as are the devices in many such flowers which have relation to cross-fertilization, in the same flowers there are devices, not one whit less wonderful, by which self-fertilization is achieved, either in supplement to cross-fertilization, or to ensure the formation of fertile seed in the event of its failure. Cross-fertilization is so widespread that it must have an important significance, for in Nature " nothing walks with aimless feet." Probably its essential purpose is the maintenance of a high standard in the race by avoiding degeneration due to inbreeding. Contrary to common thought, inbreeding is not disastrous if the parents are healthy; but if parents are not sound, the progeny must suffer. Cross-breeding may modify or even destroy weak characters and ominous tendencies. There may be dangers ahead for self-fertilized plants, no matter how healthy and successful they are at present; but at any rate they run no risk of failure to ripen seed so long as they remain sound, and they are able to achieve that important end with great economy so far as the expenditure of pollen is concerned. In their case a little pollen goes a long way, and wastage is infinitesimal.

Always remembering that pollination is preliminary to fertilization, and that cross-fertilization depends upon the successful transfer of pollen by some agency from one flower to another, we will now note the agencies involved, and some out of the many devices that have been elaborated in relation thereto.

Water, which is of prime importance in the sexual intercourse of Algæ, is used as a pollinating agent by

Plate LVII.

MARSH GENTIAN (*Gentiana pneumonanthe*),
Order *GENTIANACEÆ*.

1. Calyx
2. Flower, opened out
3. Pistil
4. Longitudinal section of ovary

Palms—a list in which lofty forest-trees are conspicuous—and also Grasses, Sedges, Rushes, Reeds, Nettles, Plantains, Hops, Hemp, and Pondweeds. Trees which, like the Birch, Hazel, and Alder, have a catkinate inflorescence are mostly anemophilous. Take, for example the Hazel (Fig. 67, p. 207). In this instance, male and female catkins are borne on the same plant. In early spring the male catkins open and lengthen, and on fine, dry days liberate a shower of pollen. This is light and powdery, and remains suspended in the air for a considerable length of time. The female catkins are not nearly so conspicuous as the male. They appear almost like buds tipped with red, but on closer examination are found to consist of a number of female flowers, each having a two-celled ovary, with two styles tipped with red stigmas. The combined stigmas of all the flowers protrude at the apex of the catkin in the form of a feathery tuft, which presents a surface of sufficient area to catch a few pollen grains when they are drifted towards it on a current of air. The Hazel nuts that we look for in autumn are the products of fertilization. Most catkinate trees, like the Hazel, produce flowers before leaves, or when the leaves are not so far developed as to present a serious obstacle to the drifting pollen. It is obvious that if the Hazel were in full foliage at the time of flowering, the leaves would render the chance of the pollen reaching the stigmas very remote.

Wind-pollinated plants produce modest flowers. Not desiring the services of insects, they waste no strength in making showy petals. They display no gaily coloured advertisement, and produce no honey. But their male flowers manufacture pollen in vast quantity, and shed

it with prodigal recklessness. It has been stated that a single blossom may produce pollen sufficient to fertilize more than 1,000 ovaries. This prodigality is evidently due to the requirements of the case. Were only a few pollen grains to be liberated, there would be little chance of any of them reaching the stigmas. As it is, out of the vast quantity of pollen that is liberated, very little gets the opportunity of serving its appointed purpose. The bulk of it is wasted. It is apparent that anemophilly involves a wasteful extravagance in the matter of pollen.

In adaptation to the means of pollination, the pollen of anemophilous plants is dusty, each grain being smooth and dry on its surface. This being so, the grains do not stick together in masses when they are liberated, but they readily separate, so that they may float singly in the air. Being very light, they do not easily come to earth. In some Conifers the pollen grains are furnished with hollow air sacs, which protrude like wings, and ensure the grains remaining afloat in the air for a long period. It is worthy of remark that the needle-like foliage of Conifers does not present the same obstacle to effectual pollination that the leaves of the Hazel or Elm would be were they developed fully at the time of flowering. Besides, it seems that in the Conifers the pollen is shed in warm, dry weather, and is actually drawn upwards by ascending currents of air. The value of this movement is fully appreciated when we observe that in the Firs (*Abies* and *Picea*) the male flowers occur on the lower branches, while the females are borne either at the summit, or quite high up. It is obvious that in these instances the liberation of

pollen during a high wind would be useless; indeed, while we speak of wind-pollinated flowers, we must dismiss the notion that high winds only are of value. They may rather be detrimental, for the best service is secured from slight air-currents and the gentlest of breezes.

In wind - pollinated plants the floral envelopes are greatly reduced, so as not to be in the way of the essential organs. The position of the flowers is such that either they may be easily shaken by the wind, or if they remain firm, their stamens are disturbed by the slightest breath. The stigmas are generally large, and furnished with spreading hairs, and exposed advantageously for the interception of drifting pollen. But in cases where stigmas are massed together they are not usually so large as in other instances. In the Reed-Mace (*Typha angustifolia*) thousands of stigmas, which are knoblike and very small, are massed together in the " mace," and thus, in spite of their diminutive size, as a mass they expose a large surface for the interception of pollen.

Cross-fertilization is the rule in anemophilous plants. It cannot be avoided in the numerous instances in which the sexes are apart on different plants, and it is assured where the sexes are both on the same plant, but in different flowers. Where the flowers are hermaphrodite, self-fertilization is generally avoided by anthers and stigmas ripening at different times. Either the anthers discharge pollen before the stigma is in condition to receive it, or the stigma ripens and receives pollen from another flower before the pollen can be discharged by the anthers with which it is associated. In this connection we bear in mind that a stigma is said to be

"ripe" when a viscid substance is exuded at its surface. It is in this substance that the pollen grains germinate. The Plantains (*Plantago*, Plate LIX.) provide us with good illustrations of the principle just described. The little flowers are arranged in spikes, and open from the base to the apex. By the time the stamens are conspicuously displayed at the base of the spike, the stigmas associated with them have done duty and withered. They benefited by the reception of pollen from another plant, and while the lower stamens are functional for the benefit of a different plant, those at the apex of the spike are not ripe, but the stigmas are receptive. The Bur-Reeds (*Sparganium*), which grow in ditches and slow streams, are anemophilous. The flowers are massed in heads that have the appearance of burs; hence the common name. The sexes are represented in different heads. In the Branched Bur-Reed (*Sparganium ramosum*) the upper flower-heads are composed of male flowers, while the lower ones are female. The female flowers mature first, and receive wind-borne pollen from a different plant in which the males are ripe. After fertilization, the stigmas wither and the ovules begin to ripen. It is then that the male flowers open and discharge pollen, which is drifted to a plant with mature stigmas. Thus, cross-fertilization is assured.

We ought not to conclude that wind-pollinated flowers are utterly neglected by insects. They certainly offer no honey, but insects are drawn to them by their appetite for pollen. Insects are to be seen either collecting or glutting themselves with pollen produced in profusion by Grasses, Plantains, and Hazels, but any service they give in exchange for what they get is

HEMLOCK (*Conium maculatum*),
Order *UMBELLIFERÆ*.

1. Flower, enlarged
2. Fruit
3. Section of fruit
4. Part of stem

negligible or non-existent. In fact, they may do more harm than good by causing pollen to be scattered at inopportune moments. Among the catkinate plants, which are generally anemophilous, the Willows are exceptional. They are pollinated by insects. The Common Sallow, or Goat Willow (*Salix caprea*) produces upright catkins, which in Britain are collected by children for use on Palm Sunday, and called "palms." The sexes are represented on separate trees, the short, thick male catkins being particularly conspicuous on account of the bright yellow anthers. The pollen is sticky, and is sought by bees on its own account, but there is the additional attraction of honey secreted by small scales at the base of each flower. This lures moths as well as bees to the service of the species. The flowers appear before leaves are developed—a very significant feature, seeming to indicate a transition from wind to insect pollination. It is probable that in the evolution of flowers wind pollination came before insect pollination. It may be that in *Salix caprea* we have a living example of a stage in the advance from anemophilly, but there are also plants which are now anemophilous that have clearly descended from insect-pollinated ancestors. The evidence for descent is found in vestiges of the more glorious days of the "good old times." The Docks (*Rumex*), although wind pollinated, still secrete a little honey. The small Meadow-Rue (*Thalictrum minus*) exhibits traces of what in its remote ancestors must have been showy and attractive corollas, and the Salad Burnet (*Poterium sanguisorba*), a member of the Rose family found in limestone districts, secretes a little honey, and its pollen is sticky.

The term "entomophilous" (Gr. *entomon*, insect) is applied to flowers pollinated by the agency of insects. A large, closely printed volume might easily be packed with an account of what is known in relation to insect pollination, and the many curious developments in flowers in respect of it, so that any review we now make of the subject cannot be regarded as comprehensive. Perhaps nine-tenths of the world's species of flowering plants are pollinated by insects.

Granting that the first flowers were wind-pollinated and consequently had no need to be attractive to sense of sight or taste, it becomes interesting to speculate on the transition from anemophilly to entomophilly. Of the general mass of primitive anemophilous plants, some were probably well adapted to their particular mode of pollination, and of such the existing species of wind-pollinated plants may well be the survivors, thoroughly confirmed in their habit, wasteful as it is in the matter of pollen. But we may imagine that among the primitive mass of flowers there were very many ill-adapted to the risks of anemophilly, yet displaying tendencies towards a better way. We may even suppose that these were not fixed species, but unsettled variations, of what may be termed "tentative experimental types." A flower which failed to produce sufficient pollen to ensure wind-pollination, and hence was threatened with extinction, may have turned a threatened disaster into a pronounced success by the chance production of a coloured floral leaf. The colour would prove attractive to insects which, in visiting the flower, perhaps in curiosity, or may be in hope of some trophy, would become dusted with pollen, and afterwards convey it to

the stigma of another flower. In that event the quantity of pollen insufficient for anemophilly would be ample for entomophilly, and, moreover, the next generation would inherit the colour-producing tendency, and in succeeding generations those plants which developed the most colour would tend to survive simply because they were more attractive to insects. The secretion of a small quantity of honey at first would be adventitious; it would not be a deliberate insect lure, but it would happen that the first flower which chanced to secrete honey would attract insects, and these visitors would incidentally become pollinating agents. Here, again, a small quantity of pollen would be effective where even a large quantity might fail in anemophilly. And the honey-producing tendency would be transmitted to posterity, being stimulated by the insects themselves, and become a most important factor in the success of the species. The development of scent would also prove of great value in entomophilly. The production of flowers which would provide shelter for insects may not have been an unimportant development in the direction of successful pollination. It is advisable to note that if, on the one hand, entomophilly has had a powerful influence in the evolution of flowers, on the other hand, it must also have had a considerable bearing on insect-life. Insects well adapted to benefit by the good things provided by flowers have survived. Thus, only long-tongued insects can secure nectar from certain flowers with long-tubed carollas, and so well adapted are insects to flowers and flowers to insects in these cases that flower and insect stand or fall together.

Colour, scent, and food form a trinity of irresistible

attractions for insects. The gaily coloured flower is easily seen by creatures that are as keenly sensible of colour as human beings, and as readily attracted by it. The larger and more conspicuous the flower the more certain is it of securing attention. Small flowers requiring the ministry of insects are usually massed in conspicuous inflorescences, such as spikes, heads, or umbels. The umbelliferous plants, of which we may take the Hemlock (Plate LVIII.) or the Cow-Parsnip (Plate XXXIII.) as types, produce an inflorescence which is a conspicuous aggregation of quite small flowers.

Scent is a considerable allurement. A number of insects, among them bees, are attracted by perfumes that are delightful to the olfactory sense of man, while there are some insects that are peculiarly charmed by odours to which human beings object. Flowers that are adapted for pollination by night-flying insects, notably moths, have a strong scent, and are usually large and of a white, or bright yellow, colour, so as to be as conspicuous as possible in the gloom. Many of them do not open and display their attractions until evening. The Evening Campion (*Lychnis vespertina*) is white, and has an agreeable perfume; it opens about 6 p.m., and does not close until about 9 a.m. Its relative, the Red Campion (*L. dioica*) keeps the shop open, so to speak, during the day, and closes at night. Unlike *L. vespertina*, which attracts moths, it benefits by the services of bees. Honeysuckle (*Lonicera Periclymenum*) and the Butterfly Orchis (*Habenaria bifolia*) are pollinated by moths, and in this connection we note the pale colour of the flowers, and that their scent is more

A. SEA PLANTAIN (*Plantago maritima*)

1. Single flower, enlarged 2. Stamen

B. BUCK'S-HORN PLANTAIN (*Plantago coronopus*).

3. Flower, enlarged 4. Cross-section through ovary

C RIBWORT PLANTAIN (*Plantago lanceolata*).

5. Fruit 6. Fruit dehiscing and showing single seed

appreciable by night than by day. The Tobacco-plant has good-sized white flowers that open at night, and at that time emit a strong perfume. The Evening Primrose (*Œnothera biennis*) has large yellow flowers, which are arranged in a conspicuous spike, and open only at night; they also are fragrant, and attract moths. It is probable that in many insects the sense of smell is keener than in man, and they can detect perfumes at distances at which we should fail to recognize them. It is in their antennæ that the olfactory sense is situated.

The smell of putrid meat and other decomposing matter, while very offensive to man, has a peculiar attraction to certain flies. There are some flowers which are specially adapted for pollination by carrion flies, and attract them by the kind of perfume in which they delight. One such is the Wild Arum (*Arum maculatum*, Plate XIII.), also known as Lords and Ladies, Cuckoo-Pint, and Wake Robin. The details of this remarkable plant are depicted in the illustration. The flowers proper are small and destitute of perianths; they are arranged at the base of an axis known as a "spadix." At the very base is a set of female flowers consisting entirely of pistils with stigmas. Above them is a group of anthers separated from the female flowers by a whorl of sterile pistillate flowers; higher still is a series of stamens that have been modified into radiating hairs. The spadix is surmounted by a club of a dull purple colour—a tone resembling that of decaying carrion—and enclosed in a sort of protective cowl, called a "spathe." We note that the club of the spadix is visible at the opening of the spathe, and that the

radiating hairs bar the constriction, or neck. Now it happens that the club of the spadix, when ripe, has a most offensive odour, yet one which is particularly attractive to a small fly (*Psychoda*). Numbers of these flies visit the plant, and press their way down to the enclosed inflorescence; they can pass the radiating hairs, which radiate with a downward inclination, on entering, but once past this barrier they find themselves in a chamber from which escape is temporarily impossible, for flight is impeded by the downward-pointing hairs. But the flies seem to offer no objection to their brief imprisonment, for the victuals are good and plentiful. The female flowers at the base of the spadix are the first to ripen; they offer the flies some honey, which is not despised, and the prisoners, in their eagerness to secure the "fluid nectareous," dust the stigmas with pollen brought from another plant, thus making fertilization possible. In due course the stamens situated above the pistils come to maturity, and powder the flies with pollen. But how can the flies get to another inflorescence, seeing that the exit from their prison is barred? The difficulty is easily overcome. The hairs wither, and the spathe droops; the erstwhile prison is a prison no longer, and the flies are at liberty to carry their burden of pollen to an inflorescence which, by its appearance and odour, advertises the fact that it is ready for the reception of visitors.

But colour and scent are, generally speaking, subsidiary attractions; they may be regarded as advertising agents calling the attention of desirable visitors to the excellent food which is free for the fetching. They make a proclamation concerning stores of sweetness, and

COMMON ROCK-ROSE (*Helianthemum vulgare*),
ORDER *CISTACEÆ*.

1. Stipules 2. Stamen 3. Calyx 4. Pistil

declare, in effect: "Honey of the finest quality given away here." No indication is given of the necessity of a *quid pro quo*, and the eager visitors pressing their way to the refectory are altogether unconscious of the fact that they are made to carry a precious vitalizing burden to the next flowers that lure them to their service.

In brief, it is mainly in quest of food that insects visit flowers, and of the triune of attractions, colour, scent, and food, the last-named is chief. The food offered by flowers to their guests is essentially honey, or nectar, and pollen. The honey bait is laid by the great majority of entomophilous flowers. I suppose most of us remember the days of our youth when we gathered the easily removed corollas of the White Deadnettle (*Lamium album*), and sucked them for honey; we also bear in mind that the sweetness came from the lower end of the corolla tube. There, indeed, is the nectary in which the honey is secreted. The nectary is a special gland for honey secretion; it is situated variously in different flowers, sometimes on stamens, very frequently in close relation to the pistil, sometimes on the corolla. Removing a petal from the flower of a Buttercup and examining it carefully, we detect a rounded scale, which forms a kind of pocket at the base; this is the nectary. In the umbelliferous plants the nectary is found on the ovary, and in the Violet it is formed from two of the stamens. The Honeysuckle secretes a large quantity of honey, frequently half filling its long corolla tube. The flower does not open until evening, when it can be visited by long-tongued Hawk-Moths. Only moths with very long tongues can explore the full length of the tube, but when

it is half full Humble Bees can, with a push, secure a little sip of honey.

Flowers that secrete honey may be visited by insects for pollen as well as honey, but there are some insect-pollinated flowers which do not produce honey, and hence pollen is the only inducement they can offer to their guests. Such plants are deemed lower in the evolutionary scale than honey producers. These pollen-flowers usually have numerous stamens, with large anthers, which produce pollen in abundance. They are visited by Beetles, which consume all the pollen they can eat on the spot, and by Bees, which collect the pollen and bear it to their hives, there mixing it with honey, and making the "bee-bread" with which they feed their grubs. Among pollen flowers are the Rose, Rockrose (Plate LX.), Clematis, Marsh Marigold (Plate VIII.), and Gorse. As a general rule, the pollen of insect-pollinated plants is sticky in contradistinction to the smooth, dry, easily scattered pollen of anemophilous flowers. Being viscid, it is not readily removed by wind, and besides it adheres to the body of an insect as it flies from flower to flower.

The insects which are of chief importance in pollination are Butterflies, Moths, Flies, Beetles, Bees, and Wasps. Of these, the Bees are chief. The Butterflies and Moths, perhaps, are next in value for this work. While some flowers, such as *Arum* (p. 313), are specially adapted for pollination by Flies, as a general rule these insects secure a lot of pelf for little service. They do not confine their attention to particular species, and, naturally, if they carry pollen from one species to another, the practical result in fertilization is *nil*. A

MEADOW CRANESBILL (*Geranium pratense*),
Order *GERANIACEÆ*.

few Beetles are of value as pollinators, but many species are worse than valueless, for they destroy the essential parts of flowers.

We cannot spare space for a detailed account of modifications of floral structure in adaptation to insect visitors, and of a host of curious devices evolved to ensure cross-fertilization, but we propose to take a rapid glance at a few examples which will indicate the remarkable ingenuity displayed in the silent flower realm.

The Meadow Crane's - Bill (*Geranium pratense*, Plate LXI.) is one of the loveliest of our meadow plants. Each flower-stalk bears two blue flowers about 1½ inches in diameter. The slender stalks, or pedicels, of the flowers are clothed with downward-pointing hairs, which prove to be a formidable obstacle to creeping insects on piracy intent. They would fain make a back-door entrance to the flower, and steal honey or pollen; the hairs frustrate their nefarious designs. Looking *into* a flower, we observe a tuft of hairs at the base of each petal; this serves to protect the nectary from insects which attempt to crawl over the petals, and get honey without giving service, and it may also be useful in preventing raindrops from diluting the nectar. Observe the pistil; it comprises a five-celled ovary surmounted by a stout style, and the style at its free end is divided into five branches—*i.e.*, stigmas. On the opening of the flower the stigmas are not spread out, but are closed together with their sensitive surfaces inwards, and the ten stamens are laid back on the petals, radiating at right angles to the style. In time five of the stamens take an erect position and shed pollen, then fall back,

allowing the remaining five to erect themselves and behave in the same way. Having shed their pollen, the stamens wither. Insects which visit the flower at this stage in quest of honey become dusted with pollen, and carry it to another flower with a ripe stigma; the stigmas of the flower under notice are not ripe, and remain closed. Later they ripen and radiate, fully exposing their sensitive surface, and an insect visitor coming from a neighbouring flower, and laden with pollen, unconsciously deposits some of the grains on the stigmatic surface. Thus cross-pollination is secured.

The familiar Primrose is a remarkable example of provision for cross-fertilization. Some Primrose plants bear flowers with long styles, while others produce short-styled flowers. The lower portion of the corolla in both cases is tubular. In the long-styled, or "pin-eyed," flowers the stigma appears at the top of the tube, and the anthers of the stamens are placed about half-way down. In the short-styled, or "thrum-eyed," flowers the anthers are at the top of the tube, and the stigma reaches only about half-way up. Honey in both kinds of flowers is secreted at the base of the ovary at the bottom of the corolla tube; it can be reached only by long-tongued insects. If we take a bristle, and insert it into the tube of a "thrum-eyed" flower, pollen will adhere to it just at the level of the anthers. Now, inserting the bristle into a "pin-eyed" flower, we find that the attached pollen will coincide with the level of the stigma. Further, when we withdraw the bristle from this flower, it will be marked with pollen from the anthers half-way down in the tube, and this mark will be on an exact level with the stigma of a "thrum-eyed"

GRASS-OF-PARNASSUS (*Parnassia palustris*)
Order *SAXIFRAGACEÆ*.

flower. The significance of this arrangement in relation to cross-fertilization is obvious.

The Grass of Parnassus (*Parnassia palustris*, Plate LXII.), a member of the Saxifrage family, beautifies bogs and moist heaths with its delicate white flowers in late summer. It stands out in virgin purity and grace against its dark background of green. The nectaries of this flower are elaborate, even ornate; they are really modified stamens, and each one of the five consists of a nectary proper surrounded by eleven radiating arms, each arm being surmounted by a yellow knob like a pin's head. The functional stamens are five in number, but they do not all liberate pollen at the same time; indeed, they ripen one by one, and each one as it is ready takes up a position in which an insect alighting from above is bound to come in contact with it, and detach some pollen. But if an insect settles at the edge of a petal, avoiding the anther, in moving towards the nectaries it is compelled by their radiating arms to take up a position near the middle of the flower, where it must needs touch the anther.

The flowers of the Sweet Violet (*Viola odorata*) are highly specialized for cross pollination by means of bees. The lower petal constitutes an alighting platform, and in addition is prolonged into a spur in which honey is secreted. Furthermore, this petal is marked with fine lines, or honey-guides, pointing to the refectory. The visiting bee touches first the stigma, pushing it upwards, then, in securing honey, its head is dusted with pollen by the stamens. When it visits another flower the pollen on the insect's head is brushed on to the stigma, and cross-fertilization ensues. But in Britain, in spite

of its lure and special devices, this flower seldom obtains a response to its invitation, and because guests do not arrive, fruit is not ripened. Yet the plant obviates failure by a curious device. It sends out vegetative runners, which root at intervals, and in due time bear inconspicuous flowers that never open. Each of these flowers contain two stamens and a pistil. The stamens yield a very small quantity of pollen, and it is sufficient for the fertilization of the ovules in the ovary. Cross-fertilization having failed the plant, it secures the ripening of seed by the production of these self-pollinating flowers, and, so far as we know, there is no detriment thereby to the species.

The pollination of the Common Ling, or Heather (*Calluna vulgaris*, Plate LXIII.), is worthy of remark. When its flowers first open they are freely visited by insects, which in sipping honey become dusted with pollen; this they carry to the stigmas of other flowers. At this period there is no possibility of other than insect pollination. But later, when nectar is exhausted, the insects are not attracted. Then the filaments of the stamens elongate, pushing the anthers outwards from the corolla, so that they may be exposed to the wind. The wind is now used as a pollinating agent, carrying the pollen to the stigmas of younger flowers. Thus, the Heather makes assurance doubly sure; it supplements entomophilly with anemophilly. The Toothwort (Plate LIII.) adopts a similar practice.

The subject of the fertilization of Orchids has been rendered classic by the work of Charles Darwin, to whose volume in relation thereto the reader is referred for a full discussion. An indication of the highly specialized

A. CROSS-LEAVED HEATH (*Erica tetralix*)
B. FINE LEAVED HEATH (*Erica cinerea*).
C. LING (*Calluna vulgaris*).

1. Under-side leaf
2. Sepal
3. Flower
4. Stamen
5. Flower, in section
6. Flower, showing four bracts
7. Section, flower

nature of these flowers will be found in the study of the Early Purple Orchis (*Orchis mascula,* Plate LXIV.). The flowers are arranged in a spike, each one being attached to the stalk by the base of its twisted ovary, and having a long spur in which honey is secreted. One petal, which is three-lobed, forms a landing-stage for insects, while the remaining two petals form a hood protecting a pair of pollen-sacs, which do not appear conspicuously like ordinary stamens. At the point of attachment of the perianth to the ovary there is a stigmatic surface. If we push a pencil-point foremost into the mouth of a flower which has not already been visited by an insect, the pencil will come into contact with an adhesive disc at the base of the pollen-sacs, and when it is withdrawn one or both of these masses, called the *pollinia,* will be found adhering by the disc to the pencil. At first the pollinia are nearly upright, but in a few seconds they bend over and forward until they are about horizontal. This little experiment illustrates what happens when an insect, say a bee, visits *Orchis mascula* in order to get honey. It alights on the landing-stage, pushes forward into the mouth of the flower, and, extending its tongue, sips at the nectareous fluid in the spur. While it is thus engaged the pollen-masses have been liberated, and have attached themselves by their sticky disc on the head of the insect, probably on one of its eyes. The bee leaves the flower with the pollinia attached to its head, and as it proceeds rapidly to another flower for more honey, the pollinia bend forward, as on the pencil. In entering the next flower, the bee, in its haste for honey, is compelled to push the pollen-mass against the stigmatic surface, and thus cross-fertilization ensues.

Notwithstanding the devices employed by hermaphrodite flowers to ensure cross-fertilization, it seems probable that in most cases self-fertilization happens occasionally, and we know of many flowers which have arrangements whereby self-fertilization can take place if crossing is not secured, or even as supplementary thereto. Perhaps one reason for the remarkable success of the Compositæ (p. 217) is their ability to ripen all possible seeds, by supplementing cross- with self-pollination. In their case the stigmas, before they finally quit business, even if they have been previously pollinated, curl over and search anthers for pollen.

The importance of insects to flowers, and of flowers to insects, is, then, enormous, and we may well marvel at their interdependence and their mutual adaptations. But before we leave the subject of pollination, we must note that animals other than insects are sometimes engaged in the work. Of what is called Ornithophyly (Gr. *ornis*, *ornithos*, a bird) we have no British instances, but in tropical and South America humming-birds engage in pollination, and the same is true in regard to the honey-birds which occur in the tropical regions of Asia, Africa, and Australia. It has been observed that a certain plant, *Freycinetia*, found in the Malay Archipelago, is pollinated by the flying-fox; also that snails, in a few cases, are useful to plants. The latter are credited with the pollination of the half-buried flowers of *Aspidistra*, and also those of the Golden Saxifrage (*Chrysosplenium*).

Turning now to the concluding theme of this chapter, we shall see, to a brief extent, how the perpetuation of

PLATE LXIV.

EARLY PURPLE ORCHIS (*Orchis mas*

ORDER

plant species is secured by the launching of posterity on a career of colonization, whereby it is not only able to multiply within due limitations, but also to "replenish and subdue the earth." In this regard we shall here take into account only the seed-producing plants.

The product of fertilization in Gymnosperms (p. 179) is a naked seed, but in the higher flowering plants—*i.e.*, Angiosperms—it is fertile seed enclosed and protected in a fruit. Fertilization affects more than the ovules; it also induces changes and developments in the ovary in which they are contained, and sometimes in other floral parts in addition. The ovary becomes the fruit containing the seeds. Thus, the "pod" of the Pea is a fruit developed from the ovary of the pistil. What passes in ordinary parlance as "the fruit" in the Strawberry is the floral receptacle become succulent, attractive in colour, and luscious. The real fruits of this plant are the little dry "achenes" borne on the surface of the toothsome receptacle. The true fruits of the Rose are contained in a receptacle that becomes succulent and externally coloured; the brilliant "hip" is not the fruit, but the protective covering of the fruits so beautifully packed within its interior. The core of the Apple is the real fruit, and the fleshy part in which we delight is the floral receptacle become succulent as a result of fertilization. In common parlance the term "fruit" is very loosely used, being generally applied to a floral product which is good to eat, or perhaps poisonous; but the term implies much more to the botanist, it suggests more than apples and pears, gooseberries or cherries, and embraces a large number of seed-containing forms which make no gastronomic appeal.

The seed, which is the essential product of fertilization, ought to stimulate our imagination and arouse thoughts too deep for words. It is a mighty potency in repose entrusted with the sacred mission of the perpetuation of the species. Nestling within that grain of wheat is the promise of a hundredfold reproduction—yea, even more, of a world's harvest. Before that seed was discharged from the parent plant the embryonic plant which it contains was set agoing, and provided with sufficient capital to maintain it in germination, and until such time as it can fend for itself. Here, truly, is a point for special note. While still in association with the parent plant an infant is conceived, and is embryonically developed up to a certain stage. When the seed is liberated the development of the embryo is arrested, to be resumed with intense vigour when it germinates under favourable conditions. We can say of the embryonic plant in the dry wheat-grain, "The child is not dead, but sleepeth." The seed is a resting-stage during which its vital part is tided over adverse conditions; it can endure great extremes of temperature, and is not seriously affected by drought. It is also a vehicle in which the fœtal plant is despatched on a journey that, it is hoped, will end in the discovery of good ground for germination. And the "young idea" in the seed is furnished with a store of food for use when the sleeper awakeneth, and resumes activity in circumstances less "cribbed, cabined, and confined," than those to which it has hitherto been restricted.

We have suggested that the fruit protects the seed; this, indeed, is true, but its protection is temporary. The essential significance of the fruit is perceived in its

relation to seed dispersal. It so happens that the fruit of the Mistletoe is attacked by thrushes and blackbirds in hard winters. Perhaps these birds are grateful for the provision, but the plant is not concerned about their welfare; it looks to itself. The succulent fruit induces the birds to eat it, but when, after the meal, they wipe their beaks in bird fashion on the bough of a tree, they detach adherent seeds, which stick to the bark in a position favourable to germination. Or if the seeds are swallowed they pass, undigested and unharmed, through the bird's body, and if fortune favours, are placed in excrement where they can follow out their not altogether noble career. The feeding of the birds is incidental; the real end in view is the dispersal of seed.

Observation of a multitude of examples confirms the conclusion that the fruit has special relation to the launching of posterity on a successful career. Naturally, in the course of dispersal many fruits, with their contained seeds, perish. This is fortunate, for if all seeds developed into plants the earth would not be sufficient to maintain the crowd. That plants should produce a superabundance of seeds is seen to be essential when we realize the risks and chances of loss through consumption by birds, and through failure to reach suitable conditions for germination. No stretch of the imagination is required in order that we may appreciate the important issues that follow satisfactory seed-dispersal. Congestion is avoided, and new ground is colonized. Suppose even a hundred seeds of a Sycamore were to fall immediately under the spreading canopy of the parent tree; they would probably germinate, but they would not secure sufficient light, air, or moisture for vigorous

growth, and even if they attained to the stature of a few years' growth they would establish a state of congestion in which no one of them would have "room to live." Crowded slumdom is as bad for plants as for human beings. The Sycamore has devised a better way; its fruit has a pair of wings, and is popularly termed a *key*. When it becomes detached from the tree it behaves like a very light shuttlecock, spinning on its own axis, and taking a zigzag course as it descends. It is frequently driven a long distance before the wind, and may come to earth, where it literally breaks new ground, and can pursue a course of vigorous and successful growth. With such provision for wind-dispersal of its fruits the Sycamore avoids the evils of congestion, and enables its kind to be perpetuated under favourable circumstances.

Attention to a few typical examples will help us to form some definite conclusions as to the means of seed-dispersal. If one sits in close proximity to some Gorse-bushes on a dry sunny day in spring or early summer, one may be assaulted by a fusillade of hard seeds. The dry warmth causes the two valves of the seed-pod to separate with a sharp crack, and when separated they curl up with great rapidity, expelling the seeds and shooting them to a considerable distance. The seed-vessels of the Sweet Violet open into three equal valves, which display the shiny seeds so that they may be dried and hardened. When this has been accomplished, each valve folds as if it worked on hinges, and the edges come near to each other. Ultimately so much pressure is brought by the valves on the glossy seeds that they are discharged like shot, with sufficient impetus to carry them several feet, or even yards. The smoothness of the

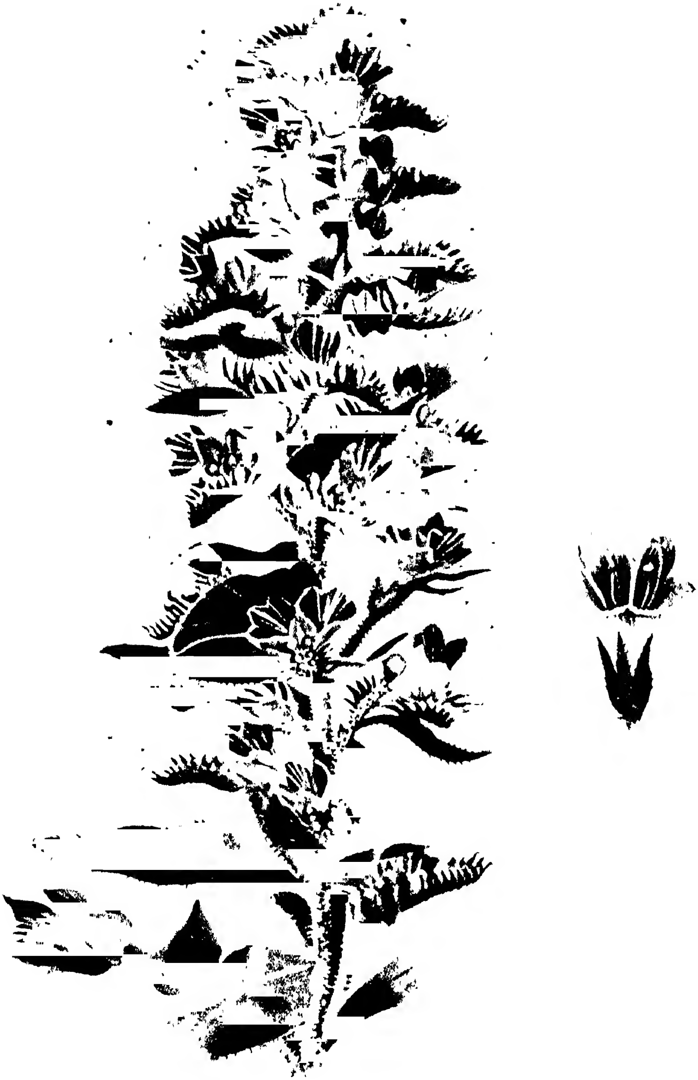
seeds enables them to slip through other vegetation and reach soil in which they can germinate. If ripe capsules of the Balsam (*Impatiens noli-me-tangere*) are subjected to even the slightest touch they will immediately open, the valves curling themselves up like watch-springs. The sudden movement is accompanied by force sufficient to scatter the seeds to a great distance. There is little wonder that this plant has been called "Touch-me-not." The Wood-Sorrel (*Oxalis acetosella*) and the Cuckoo-Flower (*Cardamine pratensis*) in dry weather scatter their seeds in a forceful manner. The Squirting Cucumber (*Momordica elaterium*), a native of Southern Europe, produces a prickly green fruit which, when ripe, springs from its stalk at the slightest touch. The seeds contained in the fruit are embedded in a viscid fluid, and when the fruit leaves the parent plant, they are expelled with a whizzing sound, and with sufficient force to carry them to a distance of several yards. In the examples mentioned in this paragraph we have, then, instances of seeds being scattered by expulsive force.

In other cases water is a transporting agent. It must be such in those aquatic plants that fruit under water; but fruits and seeds of land-plants may be carried long distances by streams and marine currents. The fruits of the Cocoa-nut Palm (*Cocos nucifera*) are often carried hundreds of miles by ocean currents, and washed ashore while still able to germinate. The nut is enclosed in a fibrous covering which makes the fruit buoyant. There are air-spaces in Water-Lily fruits which enable them to remain afloat for a time, and drift away from the parent plant. In time the seeds are freed from their "floats" by the rotting of the latter, and then they sink to the

bottom of the water. Mountain streams may transport seeds of Alpine species to levels in the lowlands. The waters of the Gulf Stream have frequently borne fruits and seeds of Mexican plants to the shores of the North Cape. To secure the fullest advantage of water transport, seeds and fruits must be able to float, and also to resist damage by the water itself. The fibrous covering of the Cocoa-nut is so woody and thick that sea-water cannot penetrate to the nut. But transport by water has great limitations; it can bear seeds only to the banks of streams and sea-coasts.

Wind is a more efficient and satisfactory transport agency than water. We have seen how well it serves the Sycamore (p. 326), and also how the fruits of that tree are adapted to wind-transport. The fruits of the Ash, Elm, and Maple are of a similar character. There is a plant of New Granada, called the Bignonia (*Bignonia echinata*), whose seeds are furnished with very delicate membranous wings, which act like the wings of an aeroplane, and enable the seed to describe hawklike circles in the air. A large bract occurs at the base of the inflorescence of the Lime-tree (*Tilia*). When the fruit is ripe the complete inflorescence becomes detached from the tree, and falls with a rotary motion head downwards; it is the bract which induces the motion, and, of course, ensures a delay in descent during which the wind may carry the fruit for some distance. A large number of fruits and seeds have hairy appendages, which enable them to be caught up by the wind. This is specially the case among the highly specialized Compositæ (p. 216), in which, with some exceptions, the calyx of the individual floret has been modified into a

PLATE LXV



COMMON VIPER'S-BUGLOSS (*Echium.*
ORDER *BORAGINACEÆ.*

but they consume only the succulent parts, and in rejecting the seeds assist in their dispersal. Should a bird happen to swallow a seed of any of these species it is passed undigested through its body. We may conclude that the climbing habit of the Wild Rose, or the scrambling tactics of the Bramble, have relation not merely to the quest for light and air, but also to display of flowers and fruit; the display of the former attracting pollinating insects, and that of the latter securing the notice of birds as seed-dispersers. No one should surmise that the display referred to is evidence of special sagacity on the part of the plants. Their habit has evolved under environmental stimulus and inherent tendency, and because of their habit it chances that they give something to birds which, in accepting the gift, quite unconsciously do the plants a service. Their habit, unquestionably, is a powerful factor of their success in the struggle for existence.

Animals other than birds also chance to assist plants in fruit and seed dispersal. A squirrel may take heavy toll of nuts. We know it lays up a hoard against hard times, and the hoard may be divided, parts of it being hidden in various places in the woods. Some of the nuts hoarded in this way may never be eaten, and so be left to germinate, while others are dropped during conveyance to the hiding-places. A few nuts dropped in different places will, on germination and growth, do much to perpetuate the species, for a single plant will eventually yield a great harvest of fruit. A Hazel-tree can afford to provide squirrels with a food-supply. It gives out of its abundance, not its penury, and if only two or three seeds are borne away, but not eaten, they

PLATE LXVI.

HERB-ROBERT (*Geranium Robertianum*), ORDER *GERANIACEÆ*.

suffice for the replenishment of some parts of the earth with the Hazel species.

The stems and leaves of the Goose-Grass (*Galium aparine*) are furnished with flinty hooks, by which the plant is enabled to clamber over other vegetation. The fruits of the plant are furnished with similar hooks, by which, sometimes to our annoyance, they readily adhere to our garments; they also cling to the fur of animals and the feathers of birds. The animals which run through the hedgerows, or brush by them, can hardly avoid these cutely devised fruits, which will cling to their hair until rubbed off elsewhere. Thus, the fruits and seeds are dispersed, and there is no wonder that the plant spreads so rapidly. The Herb Bennet, or Wood Avens (*Geum urbanum*), crowns its seeds with hooked awns, which become entangled in the fur of passing animals in the expectation of being removed on ground some distance from the parent plants. The fruit of the Burdock (*Arctium Lappa*) is also furnished with hooks. In a moment of play we may assist the species, quite unintentionally, by throwing the "burs" at a companion. They adhere to one's clothes, and may be carried some distance before being removed. In Nature, animals are instrumental in the dispersal of the fruits of this plant. The fruits of the Hound's-Tongue (*Cynoglossum officinale*) are covered with curved prickles, and are also well adapted for animal dispersal.

Man, also, and generally without deliberate intention, is a seed-distributor. Seeds of various plants become involved in his merchandise and accompany it by road, rail and water. Alien plants are thus introduced into various parts. Railway banks are happy hunting-

grounds for botanists, and waste ground in the neighbourhood of railway, canal, and steamer wharves becomes interesting on account of the "foreigners" which make sporadic appearances there.

Movement accompanied by successful "placing," one might say "sowing," of seed is exhibited by the Ivy-leaved Toadflax (*Linaria cymbalaria*). This plant is common on old garden walls. Its pretty lilac and yellow flowers reach out from the wall, courting pollinating insects, but when the fruit is formed the stalk bearing it bends over. Thus when the seed is set at liberty some of it is sure to be deposited in a crevice where it will have the chance to germinate.

But this chapter might be continued almost indefinitely with accounts of examples of provision for posterity and the perpetuation of the race. We shall conclude it with a reference to the remarkable seeds of the Stork's-bill (*Erodium*, Plate LXVII.). This plant belongs to the Geranium family; it has received its common name from the fancied resemblance of its fruit to a stork's bill. The seeds retain the long styles of the pistils, and when they are released from the fruit they fall to the ground, carrying the styles with them. Each style bears a number of silky hairs, and when released it quickly forms a spiral, after the manner of a corkscrew. In the formation of the spiral, the silky hairs are compelled to project. Gravity determines that the seed end reaches the ground, but the attached style—its tail, so to speak—may find a place among grass or the stems of other plants. The anterior end of the seed is pointed. Under conditions of moisture the little corkscrew unwinds its spiral and, of course,

HEMLOCK STORKSBILL (*Erodium cicutarium*),
ORDER *GERANIACEÆ*.

1. Flower 2. Fruit 3. Seed

lengthens. But the spreading hairs catch against the herbage with which they are in contact and resist the lengthening movement. Thus the lengthening of the style, owing to the resistance of the hairs, forces the pointed seed into the ground. One might think that with the advent of dry conditions, owing to the resumption of the spiral form by the style, the contraction would draw the seed out of the soil. But this does not occur, for the seed is provided with short hairs pointing backwards, which act like the barbs of an arrow, and are strong enough to grip the soil and hold the seed in the place it has gained. Whenever the style absorbs moisture the seed is pushed farther into the soil. Ultimately the useful appendage decays, but not before it has served its remarkable purpose. It should be added that the seeds are dispersed by wind, but even when the air is still they literally crawl over the ground, by the coiling and uncoiling of the style, until they come to rest on a site suitable for the operation just described. The humidity of the atmosphere is sometimes tested by means of Stork's-bill seeds. When the atmosphere is laden with moisture the styles straighten out; they coil when the air is dry.

CHAPTER XI

THE DEFENCES OF PLANTS

THE modern business man feels intensely the commercial struggle for existence. If one approaches him with the question, " How is business ?" the answer will generally involve the assertion, " The pace is getting ever faster, and competition is very keen." Our commercial friends feel the weight and oppressiveness of competition, and know that if they are to succeed in the struggle they must be ever alert and ingenious, and ready to outstep their competitors. Methods must be brought up-to-date, old machinery scrapped and replaced by better, wise economies must be instituted, and protective measures adopted. He who can invent something new and universally useful is likely to outstep his competitors, and find openings for business and financial success that do not fall to the lot of the individual who is unduly conservative.

Competition is as keen, if not keener, among the plants, and it is utterly ruthless. Here the fight is without " the gloves," and in no way modified by virtue or conscience. The strongest and fittest will survive; the weakest must go to the wall. The established flora of a district, that which is vigorous and can be reckoned on, has survived many vicissitudes and remains fit; it has succeeded in the struggle and is the witness of its

PLATE LXVIII.

MEADOW-SWEET (*Spiræa ulmaria*), ORDER *ROSACEÆ*.

success. It has defended itself against the aggressor, and adapted itself to the demands of its habitat; the weaklings that have attempted to resist its victorious progress have been thrust aside and have perished by the way, in most cases leaving not a trace of their former existence. The plant which is to be successful must hold its own ground and, if need be, extend it; it must not allow itself to be suffocated by an aggressor, it must have its place in the sun, and it must make the best possible provision for the perpetuation of the race. It has not only to compete with highly organized species, but must defend itself against the incursions of disease-engendering microbes and fungi. It must be prepared for changes of temperature and other climatic vicissitudes. In drought it must conserve its water; at all times its protoplasts must be rendered comfortable. Its mechanics must be so well ordered that it may resist physical strains. It must be able to stanch its wounds, lest they provide a vulnerable point in its armour, at which microbes can attack with success, or lest it bleed to death. It may be attacked and eaten by animals if it does not render itself objectionable to them. It may also be trampled upon, but without mortal injury, if only it has sufficient resources. Many plants, although gravely wounded, are not beaten; they fall to rise again.

In all its parts and in every stage of its development, a plant is liable to attack from some quarter. The seedling period is one of much delicacy. Fortunately, the earth in which germination takes place affords protection during the earlier developments, but so soon as the tender plant emerges from the ground it

is liable to the attacks of many predatory foes, as well as climatic exigencies. Without doubt it is during the seedling period that the plant is most vulnerable, and that the issues of its existence are most problematical. The mortality among seedlings must be exceedingly high. Herein we see the necessity for the production of abundance of seeds; they must not only be produced in sufficient numbers to provide against wastage in dispersal, but also against high infantile mortality. The species survives by force of numbers. Nature is careless about individuals. It is the race that counts, and it usually happens that the individuals which survive in the struggle for existence are the best fitted to exist, and thus be the means of perpetuation of a vigorous race.

We have already discussed (p. 264) means of assuring a satisfactory transpiration current and devices which prevent it being unduly checked. We have in the same place indicated some methods of avoiding excessive transpiration. The all-important stomata are usually most numerous on the undersides of leaves, where they are variously protected lest they should suffer interference in the exercise of their duty. The tender protoplasts of leaves and other green parts are screened from excessive heat and light and fortified against rain and hail in various ways.

All parts of plants are subject to the attacks of fungal and bacterial fiends. Spores and germs are almost omnipresent, floating about in the air, and seeking some weak point in a plant's defences where they may find lodgment and flourish. They induce some of the most devastating diseases. It so happens

MARSH WOUNDWORT (S
ORDER *LABIATÆ*

1. Calyx 2. Flower, enlarged 3. Fruit

that plants have developed both inward and outward characters which are resistant to such attacks. There are certain by-products of their chemistry which have an important value in this respect. We do not venture to assert that these by-products have been deliberately produced for the purpose; on the reverse, we are disposed to declare that the plants which yield them chance to have established thereby an immunity which has been an important factor in their survival. Among these products are cork, latex, gums, resins, turpentines, ethereal oils, etc. The resin exuded from a cut made in a Pine branch is an effectual means of closing the wound and warding off bacteria. Latex is a powerful antiseptic, a fluid of a most complex formation, generally milky in appearance; it is developed in lengthened cells, which form tubes running up and down the plant and occur most freely in the cortex or bark of the stem. It is from the latex of the Rubber plants that the rubber of commerce is obtained. In some plants latex is very freely produced; opium is from the latex of the Opium Poppy. The Greater Celandine (*Chelidonium majus*, Plate XXIII.) develops an orange-coloured poisonous latex in all its parts; it exudes from a broken stem or leaf-stalk and congeals over the wound, forming a protection which is proof against bacteria and fungi. The milky juice, really the latex, found in the Lettuce, Dandelion, and Sow-Thistle, is familiar to all who have even the most superficial acquaintance with these plants. A potato from which a piece has been cut quickly develops a layer of cork cells across the exposed surface of the cut, thus preventing evaporation of moisture and offering resistance to fungi and bacteria. A layer of

cork cells appears at the point from which the withered leaf of a deciduous tree falls, so as to allow no point of weakness whereat fungi and bacteria could penetrate. The fall of the leaf is an interesting phenomenon. The leaf has done its chemistry and served its many uses; the products of its labours are withdrawn into the branch, and, before the leaf is allowed to fall, the layer of cork cells is formed. When it has satisfactorily bottled up the withdrawn products and established a sufficient protection for a tender spot against invisible foes, the plant permits the severance of the leaf, and the protective layer of cork is seen as a "leaf-scar." The scent of plants is due to the ethereal oils they produce. While these oils serve to attract pollinating insects, many, if not all of them, are fatal to bacteria.

The so-called "sleep" of flowers and leaves is a provision against cold and rain. The huddling together of the florets of Daisies and Dandelions is a means of heat retention and also a protection of the tender essential organs, as well as the pollen, against the incursions of rain. We notice how on cold days and during the night these flowers take up their "sleep" attitude; also how they are closed on dull wet days. The flowers of the Crocus are erect, and if the yellow perianth leaves did not form a canopy over the tender stamens and pistil on a wet day they might be seriously damaged by hail or rain. The flowers of the Crocus are open only during periods of sunshine, when the essential organs can sustain no damage from rain, and when the pollinating insects are abroad. One might instance many devices for the protection of pollen. The flowers of the Snowdrop and Harebell are pendulous, and their

floral leaves act as an umbrella. The flowers of the Lime-tree are protected by foliage leaves; raindrops roll off their edges and do not reach the sheltered flowers. A member of the Buttercup family, the Globe-flower (*Trollius Europæus*), produces blooms which never open so as to display their essential organs; the floral leaves curl over and form a yellow ball. Bees can push their way in to the concealed organs and leave the flower without much trouble, but raindrops are turned aside.

A cordial welcome and a reward are offered to pollinating insects, but an insect which attempts to steal honey without giving a *quid pro quo* is most unwelcome. Among the defensive arrangements which are calculated to thwart these burglarious intruders are hairs and sometimes sticky secretions. Honey-stealers which crawl up the stems of some members of the Campion family in the hope of securing honey through the back-door, so to speak, on nearing the flowers find themselves caught by a viscid secretion which effectually bars their progress and, in most instances, causes their death. The sticky fluid is secreted by hairy glands, and is said, in some cases, to capture marauders in order that they may be afterwards digested. It is not unlikely that in the plants referred to, notably the Catchflies, and also in the Rue-Leaved Saxifrage (*Saxifraga tridactylites*) and the Hairy Stonecrop (*Sedum villosum*), we have instances of an early stage in the development of the carnivorous habit. What, indeed, would be more economical than that a captured marauder should be turned to account as food? The Wild Teazle (*Dipsacus sylvestris*) is well armed against insect-bandits as well as

browsing animals. Prickles occur on the stems, the midribs of the leaves, and the bracts of the flowers. Insects, and even caterpillars, which try to reach the flowers by way of the stem have to negotiate a whole armoury of prickles, which usually baffle them. But it also happens that the leaves arise from the stem in pairs, their bases being united to form a species of cup in which water collects. Insects thrust back by the stem-prickles frequently tumble into the water and get drowned. The Teazle is not beyond making use of wastage; the macerated bodies of the insects appear to make quite excellent broth, and this is absorbed by the plant by means of strands of protoplasm, analogous to root-hairs, which are extemporized in the leafy cup for the purpose. The stems, leaves, and flower-stalks of many plants are so hairy that, considering the size of small insects in proportion to the length and arrangement of the hairs, an attempt on their part to crawl through them would be more than an equivalent of a man striving to force a path through the dense jungle. But we must not conclude that plant-hairs have no other use than that just indicated; they have, indeed, a greater significance, as we have before shown (p. 265).

Either directly or indirectly animals depend upon plants for food, so that in the very nature of things the consumption of plants by animals is enormous—indeed, incalculable. The supply of plants suitable for animal feeding must be more than adequate to the demand; no matter how great the toll exacted on a species, if it is to perpetuate its kind, it must always ensure a balance to its own credit. The Diatoms (p. 28) consumed by marine animals every day must be " as the sand on the

seashore for number," yet, in spite of the myriads that hourly disappear, there is no evidence of diminution; the credit balance is as large as ever. That balance is certainly due to a wonderful capacity for reproduction; Diatoms survive by force of numbers. And so must it be with a goodly number of plants, especially those of the humbler orders. The weight of Grasses eaten by animals in the course of a year, could it be calculated, would be discovered to be vast; yet Grasses survive, and are nearly ubiquitous. Here we have not only increase by seeds, but great vegetative activity and recuperative power. If in summer-time we are to keep our lawns in a condition pleasing to the zealous gardener, we must, especially in warm, moist weather, run the mower over them once, or perhaps twice, a week, so speedy and vigorous is the growth of the grass. If, on the other hand, the grass is dried and burned by a scorching sun, it speedily becomes green after a good rain. Doubtless, the vegetative possibilities and recuperative power of Grasses constitute a most important factor in their ability to more than survive the incursions of grazing animals and the effects of drought. And, in addition to having to supply grazing animals with a huge quantity of food, Grasses have also to yield of their substance to the appetites of numerous insect larvæ. The larva of the *Tipula*, or Crane-Fly, familiarly known as "Daddy-Long-Legs," feeds underground on the roots of Grasses, and does much damage: this larva is known to gardeners and others as the "leather-jacket."

But there are large numbers of plants that are avoided by browsing animals, and there are some which they would fain eat, but dare not. All these species are pro-

tected by various means. Some are poisonous, and animals seem to avoid them instinctively; it is not improbable that certain curious distinctive characters of poisonous plants are warning features—the lurid purple flowers of the aconite (*Aconitum napellus*) and the dingy-yellow flowers of the Henbane (*Hyoscyamus niger*, Plate XX.), with their curious purple veining, are examples of what is meant. The adage " What is one's food is another's poison " is illustrated by the Deadly Nightshade (*Atropa belladonna*). This plant is poisonous to men and cattle, but the larva of a certain kind of beetle thrives upon it; probably the toll exacted by the larva is not sufficient to impair the vigour of the plant. It is said that rabbits may eat it without fatal consequences. The Poppies and the Foxglove (*Digitalis purpurea*) are poisonous.

Other plants, though not actually poisonous, have an objectionable taste, and equally as objectionable an odour. The Herb-Robert (*Geranium Robertianum*, Plate LXVI.) and the Woundworts (*Stachys*, Plate LXIX.) are disagreeable both in taste and smell, the latter being accentuated when the plants are crushed. The Sweet Briar (*Rosa rubiginosa*) has a scent, due to secretion of an ethereal oil by foliage glands, which is attractive to men and insects, but probably a stench in the nostrils of a grazing beast.

Many plants which might provide animals with delectable food are protected from their incursions by external characters. Leaves may be too tough for ready consumption, or be rendered objectionable by a clothing of hairs. In many species of Mullein (*Verbascum*) the leaves are clothed with branched, radiating

hairs which are readily detached; a touch with the finger is sufficient to remove a goodly number, and it will be noticed that the detached hairs cling to the skin. A grazing animal that attempts to eat the leaves will have an unpleasant sensation due to the manner in which great numbers of the hairs cling to the mucous membrane of its mouth and incommode its activity. Once having had such an unpleasant experience, the animal will in future leave the plants severely alone. In the human mouth the hairs induce almost unbearable irritation. The Comfrey (*Symphytum officinale*, Plate XXVII.) is armed with stiff bristles which prick like needles, and the beast that can consume the plant in comfort would need to be very hard in the mouth; other plants belonging to the same family—Borragineæ—are similarly armed. The stinging hairs of Nettles (*Urtica*) are obviously protective; they are ingeniously contrived. Each hair is a tubular, flinty needle terminating in a tiny knob which closes the tube. When touched the knob breaks off, and the point of the needle pierces the skin. An irritant fluid is contained in a sac at the base of the needle, and the pressure upon the latter causes the fluid to be forced through the tube and injected into the flesh. The stinging-hair of a nettle is a natural hypodermic syringe. It operates on exactly the same principle as the poison fang of a viper. The British Nettles (*Urtica urens* and *U. dioica*) have a sting which is irritating, but not severe, yet it is sufficient to ward off browsing animals. Curiously enough, the larvæ of the small Tortoiseshell Butterfly (*Vanessa urticæ*) can feed upon these Nettles with impunity, but the damage which they do is negligible. The stings of *Urtica*

stimulans of Java may have as disastrous consequences as snake-bites. Horses have been known to have been killed by the stings of the Australian tree *Laportea moroides*.

Other points in the protective equipment of plants by which browsing animals are induced to maintain a respectful distance are thorns, spines, and prickles.

Thorns are really shoots which, through lack of nutrition, have failed to develop, and hence have become woody and pointed. In the Hawthorn (*Cratægus Oxyacantha*) the tender young leaves are protected by thorns, and similar protection is afforded by the thorns of the Blackthorn, or Sloe (*Prunus spinosa*).

A spine, strictly speaking, is a leaf, or part of a leaf, modified on account of disturbances in nutrition. The spines of the leaf of the Holly (*Ilex*) are the sharply pointed ends of leaf-veins. The Gorse, or Furze, is most effectively protected by a complete armoury of branches which have been modified into thorns, and leaves that are aborted into spines.

Prickles are outgrowths of the epidermis and the tissue immediately beneath it; they may be regarded as hairs, many-celled, and of larger growth. They are usually quite easily detached without tearing or seriously impairing the epidermis. The principal use of the prickles of Roses and Brambles is in climbing, but they also serve to ward off animals. The Scotch or Burnet Rose (*Rosa spinosissima*, Plate LXX.), which does not often grow more than a foot high, and occupies dry, bushy places, heaths, and sandy sea-coasts, simply bristles with prickles of varying length. These prickles are not suited for climbing, nor does the plant attempt

BURNET-LEAVED or SCOTCH ROSE (Ro
ORDER *ROSACEÆ*.

to climb; they stand out nearly at right-angles to stems and branches, and are not hooked. Doubtless, in consideration of the open situations in which the Scotch Rose grows, and the possible attentions of browsing animals, it needs all its warlike, threatening prickles.

We must not allow our imagination to run riot in regard to these so effectively armed plants. We might, in the exercise of mere fancy, come to the conclusion that thorns, spines, and prickles have been deliberately evolved as a determined protection against animals, but the facts do not justify us in so doing. Take, for example, the two varieties of the Common Rest-Harrow (*Ononis*); one grows in exposed places, in the haunts of browsing animals, and is armed with spines; the other has few, if any, spines, and grows where " thieves do not break through nor steal "—not in heaven, indeed, but in a sheltered earthly paradise of its own. Are we to say that the spiny variety has evolved spines as a deliberate protection against browsing animals, and that the spineless form dispenses with spines because it does not need protection from animals in the haunts it favours? A poet might here find an opportunity for a draught upon his inner consciousness and a moving rhapsody on a singular design. The cold truth, however, brings us to earth. The spiny form is an adaptation to an open environment and defective nutrition; the spines are modified leaves, and an evidence of the reduction of the plant's transpiring surface; in brief, the modification of the leaves into spines effects a check on transpiration, and the reduced transpiration current leads to defect in nutrition. The spines would be present on this account even if there were not a browsing

animal in existence. The spineless, or less distinctly spiny, variety of Rest-Harrow grows in situations where transpiration does not need a severe check, and hence where nutrition is normal. But if we have accounted for the spines in this matter-of-fact fashion, there is yet room for mild rhapsody, for the adaptation is remarkable. The armoury of plants has been called into existence by physiological necessity; herein we discover its primary significance; but it happens that it serves more than its essential use, for it chances to be a means of defence against animals—a not unimportant factor in survival. We have seen that in the Cacti (p. 263) the stem is green and succulent, but the leaves have been reduced to spines. This is a purely physiological adaptation to desert conditions, but it happens to have an important secondary use, for browsing animals would need to be sore distressed by hunger and thirst before they would attempt to satisfy their appetite at the expense of sore and irritated mouths. These desert plants survive because they have evolved a form which is doubly useful; it conserves the water-supply, and at the same time keeps animals at bay.

Kerner, in his *Natural History of Plants*, directs attention to the manner in which young trees of Beeches, Oaks, and Larches, if they grow where they can be reached by oxen, sheep, and goats, have their young shoots and the attached leaves eaten by these animals. It happens that the portion of a shoot left on the tree after its mutilation dries up, but its hinder part remains alive. One effect of the pruning by these animals is a vigorous production of buds on the living part. Shoots arise from these buds next spring, and the pruning by

YELLOW ARCHANGEL (*Lamium*
ORDER *LABIATÆ*.

animals may be repeated with similar results. After repeated prunings the tree has the appearance of a garden tree that has been pruned into some conventional shape. But after some years of pruning, the time comes when animals leave the tree alone. The tips of the mutilated shoots which become dry and hard are eventually so crowded, and the branches become so thick and sturdy, that a grazing animal attempting to reach young leaves pushes its nose against hard points that hurt in a tender spot. This is a suggestive issue. The aggressor against a defenceless tree unconsciously causes the eventual appearance of a defensive armour, which renders the tree immune to further attack. Beech hedges that are regularly pruned develop armour of the same description.

Many plants find safe refuge under hedges and trees which keep grazing animals at bay by means of their protective armour. On a hedge-bank such plants as the Stitchworts, Wild Vetches, Vetchlings (*Lathyrus*) Ground Ivy, Wild Parsley, Sweet Cicely, White Deadnettle, and Chervil, grow with great success and unmolested in spite of the fact that a number of them make excellent fodder. The Sweet Cicely (*Myrrhis odorata*, Plate XVIII.) is one of the Umbelliferæ; it produces fruits with a pungent aromatic flavour, which probably serves to prevent birds from attacking them. The White Deadnettle (*Lamium album*) is frequently seen in association with Stinging Nettles, and when this is so, its warlike neighbour may keep grazing animals at a distance. It also happens that this plant has leaves which in general appearance closely resemble those of the Stinging Nettles. Perhaps animals are deceived by

the resemblance, and consequently leave the plant alone.

It is a matter of observation that Rhododendrons and other low-growing shrubs are not " barked " by rabbits, and that grazing animals do not eat their leaves. Neither do they consume Horsetails (*Equisetum*), or tackle the Crowberry (*Empetrum*) and Cowberry (*Vaccinium Vitis-Idæa*). The reason is that these plants, as well as others not mentioned, form a thick cuticle, and deposit therein a quantity of silica. An animal that ventured to eat these plants would have a bad attack of indigestion.

In assimilating proteins, most plants form a poisonous salt, oxalate of lime, as a by-product of their chemistry. This salt is deposited in the tissues in the form of single or aggregated hard crystals. They are plentifully developed in the roots of the Rhubarb and in the outer parts of a number of bulbs. It has been demonstrated that in the case of bulbs, at any rate, the crystals are a protection against the ravages of snails.

Flowers, scented or otherwise, are usually avoided by grazing animals. It is, of course, important that, in view of their function, this should be so. But how is the phenomenon to be accounted for ? They may not be molested because they are posionous, or that their flavour is disagreeable, or for the reason that they are not particularly nutritious. In cases where flowers are freely eaten, the plant, if it is to survive, must be able to reproduce itself by vegetative means. The Daisy must have vast vegetative resources, judging by the manner in which it increases on our lawns, in spite of the fact that the lawn-mower does not permit the flowers to form seed.

In discussing seed disposal, we have learned how birds eat certain ripe fruits and scatter the contained seeds. It is necessary to point out here that it would be disastrous to the plants concerned if birds attacked the fruits while unripe, and before the all-important seeds were properly developed. We know that it is only indiscreet children with a voracious appetite who experiment with unripe fruits, and they usually suffer the penalty of their indiscretion. Birds are wiser: sour, hard, and unpalatable unripe fruits do not attract them; they wait until they are ripe, and when they are ripe and sweet the seeds are ready for dispersal. While the fruits are ripening, they are covered with a skin which keeps water from without getting in, and the water that is in from evaporating. Some fruits are covered externally with "bloom," such as occurs on the plum and grape. This bloom consists of wax, which is antiseptic, and wards off fungi and bacteria. Every vine cultivator knows how important it is to avoid disturbing the bloom of the grape; at any point where it is removed, fungi and bacteria may attack and induce rot.

The manner in which certain Acacias are protected by warrior-ants against the incursions of leaf-cutting ants has already been described (p. 291). This is a type of police duty which cannot be observed in Britain, because here we have no leaf-cutting ants. But if we examine the under surface of the leaves of such trees as the Horse-Chestnut, Elm, or Lime, we may chance to observe little groups of hairs in the forks of the veins, which form a shelter for a number of very active mites. These can be readily seen with the aid of a hand-magnifier, such as any student of plants will find it

necessary to carry. It would seem that these little mites emerge from their shelter during the night, and pounce upon bacteria or such spores of algæ, lichens, and fungi as happen to settle in their neighbourhood. Apparently the mites pay for the shelter given by the leaves by protecting them from the attacks of very subtle foes. A tiny insect, *Cynips argentea*, produces peculiar galls on the Oak (*Quercus pubescens*). It chances that these galls secrete honey. Ants are attracted by the honey, and render valuable service to the tree by warding off predatory snails and larvæ. The reader will hardly need to be reminded that such protection as is afforded in this remarkable case is accidental, not designed. The insect happens to find a vulnerable point in the plant, and a gall results; the secretion of the honey is the result of peculiar stimulation; the ants are attracted by the honey, and they chance to serve the plant by their warlike attitude to certain of its enemies.

SEA HOLLY (*Eryngium maritimum*),
Order *UMBELLIFERÆ*

CHAPTER XII

ECOLOGY: THE NEW FIELD BOTANY

THE modern science of Botany, with its exact method, many branches, and most extensive literature, has emerged, "line upon line and precept upon precept," from the early study of plants in a little enlightened age. In those times the medicinal qualities of various species were the chief subject of inquiry, and not a few plants were used in superstitious rituals and endowed with purely imaginary mystic virtues. Although the early herbalists used many plants in concocting elixirs that were more nauseous than efficacious, they nevertheless made some valuable discoveries in the medical line, for which we owe them some gratitude.

Those early students of plants must have had great difficulty in the identification of species, for there did not then exist any system of classification, and the nomenclature was of a loose and haphazard nature. The same species received different names in different localities, and it often chanced that the name associated with a particular plant in one district was applied to quite a different plant in another. The confusion was great, and gave rise to difficulties and mistakes. A haphazard and traditional mode of plant study, in which there was no scientific method, obtained until the coming of the great Swedish botanist Linnæus, who

was born in 1707, and died in 1778. It is true that prior to the advent of this genius numerous attempts had been made to classify plants, but it was Linnæus who resolved order out of chaos by establishing a system of nomenclature and classification which has paved the way for the accurate identification of species. His idea of a binomial nomenclature is that which is at present adopted; it has stood the test of time. In this system of naming, each plant has two names, one generic and the other specific; the generic name being, so to speak, a surname, while the specific is a Christian name. The species is a unit of classification, while the genus is a group of species possessing some characters in common. Thus in the genus *Lamium* we have *Lamium purpuerum*, the Purple Deadnettle, and *L. Galeobdolon*, the Yellow Archangel (Plate LXXI.). Both these species have distinctive characters, entitling them to specific rank, but they have some features in common, on account of which they are associated in the genus *Lamium*. In their turn the genera are associated in Natural Orders, and these are arranged in Groups. Although the binomial nomenclature of Linnæus is still in use, his system of classification has been superseded in Britain by that of Bentham and Hooker, and on the Continent by that of Engler. Engler's system has much to be said for it, and seems likely to come into greater prominence and use in Britain and elsewhere. But the perfect system has yet to be evolved.

When an orderly classification and universal nomenclature of plants came into being, the study of botany was greatly facilitated, and it began to progress on scientific lines. An orderly and healthy field-botany

YELLOW-HORNED POPPY (*Glaucium.*)
Order *PAPAVERACEÆ*

emerged. Collections of dried specimens were the order of the day, and the *summum bonum* of the early field-botanist was the discovery and naming of a new species. Although the zealous field-botanist and compiler of lists of species found in given areas has always been in evidence, there came into being, in due course, a new and useful activity in the ranks of plant students. This took the form of laboratorial research into minute details of structure and physiology. It has been facilitated by the extension of chemical knowledge, and improved methods of microscopical research. The highly specialized nature of laboratory inquiry has, perhaps, occasioned the divorce of its devotees to some extent from field operations, yet it has added great stores of knowledge of the utmost value. The field-botanist has served science by the discovery, naming, and systematizing of species; the laboratory worker has discovered secrets of life and structure.

Within quite recent years a new form of botanical inquiry has come into existence. It has been made possible by the work of the old field-botanists and the newer laboratory workers. Moreover, it may be regarded as the logical outcome of their efforts. Equipped with the noble heritage of knowledge bequeathed by former observers, the botanist is once more finding his way into the fields, bent upon a newer phase of inquiry, which may rightly be termed the *new* field-botany. It is a healthy, out-of-doors study of a very comprehensive character, for it involves all the old features of botanical inquiry plus something more.

The new field-botany is Ecology (Gr. *oikos*, a house). Haeckel defined Ecology as the science treating of the

reciprocal relations of organisms and the external world. So far as plants are concerned, we will say that this new and welcome science is the study of plants in their haunts, or in relation to their environments. The ecologist takes cognizance of plants in community rather than as distinct individuals. As Warming, one of the pioneers in the new botany, indicates, Ecology " teaches us how plants or plant-communities adjust their forms and modes of behaviour to actually operating factors, such as the amounts of available water, heat, light, nutriment, and so forth." We commonly differentiate between the plants which are associated in distinct habitats; we talk about woodland plants, knowing that in woodlands there are species peculiarly adapted to flourish there, and forming a botanical community. If we wish to secure a woodland species, we should not be so foolish as to search for it in a salt marsh. We also speak of the plants of the seashore, of the swamp, the moor, heath, dune, and mountain, and in doing so form in our minds more or less distinct pictures of communities of plants characteristic of the sites mentioned. Now, the ecologist seeks to know how it happens that certain plants are associated in particular habitats, giving a marked floristic physiognomy to the areas they occupy. In making his inquiry he has to take account of numerous factors.

The first stage in the study of the plant-ecology of a district consists in finding out what species are associated in similar habitats. Take a moor here, and a moor there, it is known that there are certain plants which give a distinctive physiognomy to moors, and are to be found in this or that patch of moorland. The ecologist

must be able to identify these characteristic moorland plants, so that he may make careful note of the various species, and determine those which predominate, those which are subdominant, those which occasionally occur, and also those that are rare. Rarities and occasionals, however, while interesting, have not the principal interest to the ecologist; he is mainly concerned with the plants which give a distinct floristic physiognomy to the habitat. To a student who has an "eye" for landscape, and is able to identify plants, this first stage in ecological inquiry is not difficult.

Having noted the various species that form distinct communities, the ecologist proceeds to make further inquiry. He has to ascertain why a particular species has a peculiar habit and is found in a given environment, why various species are associated in communities, why those communities have a characteristic appearance, and, moreover, he must try to understand the economy of the plants concerned, the nature of the demands they make upon their environment, and the manner in which they are adapted thereto. This is a big inquiry, but a worthy and interesting one. It must be remembered that a plant which thrives in a given environment is both internally and externally in harmony with it. If the natural conditions change and the species cannot meet the demands of the change, it will go under in the struggle for existence, and its place will be occupied by other species better adapted to the changed conditions.

In studying plants in relation to their environments, the student has to take into account a number of ecological factors, such as light intensity, temperature,

water, air, and soil. How essential light is to the healthy life of green plants we already know, and we have, to some extent, seen how plants behave in respect to light. A degree of heat is necessary to ensure growth, but both light and heat are powerless in the absence of water, so far as plant-life is concerned. From the air plants obtain oxygen in respiration and carbon dioxide for the formation of carbohydrates. Plants also are affected by movements in the air—*i.e.*, wind. Soil is a very important factor, and has to be studied in relation to subsoil, and quantity and quality of humus. Various soils differ in the amount of nutrient salts they contain, the quantity of water they are able to retain, and the extent to which they are permeated by air. Soils also are affected by worms and bacteria. The exposure of the habitat is also a factor worthy of note. In the Edinburgh district wheat is ripened on ground with a southern exposure up to the altitude of 700 feet above sea-level, but on a north exposure the altitude at which it can be successfully grown is 200 feet lower.

Of all the factors in plant-ecology water is chief, and the botanist is now in the habit of classing plants according to their water environment. He divides them into four great classes—Hydrophytes, Hygrophytes, Mesophytes, and Xerophytes.

Hydrophytes (Gr. *hudor*, water; *phyton*, plant), or aquatic plants, are specially adapted for life in water. Some of them are free-floating, some are entirely submerged, while others are rooted in mud, and have floating leaves with their upper surface exposed to air. Light reaches the true aquatic through the medium of water, while oxygen, carbon dioxide, and nutrient salts, are

obtained in solution in the water. Hydrophytes have a very considerable internal air space, thin cuticles through which absorption is easy, and a greatly reduced vascular system.

Hygrophytes (Gr. *hygros*, moist) are land-plants adapted to very moist conditions, such as obtain in marshes, bogs, and the margins of ponds and lakes.

Mesophytes (Gr. *mesos*, middle) occupy an intermediate position between hygrophytes and xerophytes.

Xerophytes (Gr. *xeros*, dry) are land-plants which are able, by virtue of their structure, to endure periods of drought and to flourish on dry soils. They have particular means of preventing loss of water by excessive transpiration, which might be induced by heat, a dry atmosphere, wind, and intense light. These means are varied, including reduction of leaves to spines, as in the Cacti and Gorse, or the development of fleshy stems and leaves, as in the Stonecrops (*Sedum*). All desert and rock-plants are xerophytes. They are also adapted to conditions calculated to reduce root-absorption, such as the presence of salt and humic acid in the soil, or a cold or dry soil. Many xerophytes occur in swamps and salt-marshes where water, of a sort, is plentiful, but it is not of the quality required by hygrophytes; it may be heavily charged with humic acid or with salt, and were not absorption and transpiration severely checked, these substances would enter the plants in disastrous quantities.

Most British plants are classed as Tropophytes (Gr. *tropos*, change); they are so named because they manifest different characters in summer and winter. Our deciduous trees are tropophytes. In summer they are vege-

tatively active by means of their foliage; in the autumn the leaves fall and vegetative activity is arrested; in winter the trees are destitute of foliage and assume a pronounced xerophytic form, in which vegetative activity is hardly existent. Herbaceous perennials lose all their aerial vegetative parts in winter; they die down to the ground, and endure the cold season by means of their underground organs, which are xerophytic for the time being. There are xerophilous tropophytes which, during their summer activity, are adapted to life in such physically dry places as sand-dunes, or such physiologically dry situations as salt-marshes. Most of our annuals and biennials, as well as our deciduous trees and herbaceous perennials, are mesophilous tropophytes, being in summer adapted to existence in intermediate conditions as to water-environment. The annual plants, which pass through all stages of existence in a single season may be said to endure winter in the form of the seeds they produce. Seeds are most pronouncedly xerophytic. Marsh and bog plants are hygrophilous tropophytes, being in their summer condition in a constant moist environment to which they are well adapted.

In order that plant-communities may be aptly classified and described in an ecological survey, certain terms are made use of, and in the study of plant-ecology it is essential that the student should appreciate the significance of these terms. Ecology, be it noted, is in its infancy; it is by no means stereotyped, and any conclusions as yet reached must be regarded as more or less tentative. There are differences of opinion among investigators in various countries as to the best terms to employ in relation to plant-communities. The terms

which we proceed to explain have been adopted by the Central Committee for the Survey and Study of British Vegetation.

First there is the *Formation*. Warming defines this as "a community of species, all belonging to definite growth forms, which have become associated together by definite external (soil or climatic) characters of the habitat to which they are adapted." Elsewhere it has been defined as "the vegetation of a district determined by climate and soil." The plants which are associated with moorlands constitute, in their whole complex, a moorland formation. The vegetation of a sand-dune is a dune-formation. The formation embraces one or more *Associations*, which are smaller plant-communities, related to the formation as species to a genus. Then within an association there may be *Societies*, still smaller communities, composed of aggregations of individual species. Take, by way of illustration, the plant-formation associated with clay soils. This formation may embrace a woodland and a grassland association. The woodland association, in its turn, may have, here and there, aggregations of individual species — that is, societies of Wood Anemones, Wood Sorrel, Wild Hyacinths, Primroses, and Dog's Mercury. The formation is closely related to a definite habitat, and in thinking of it the ecologist has in mind not only the plants that enter into the formation, but the habitat in which they live. A formation has been likened to a city in which there is a nice balance of human coteries, and in the minds of some it is regarded as being analogous to the formation of the geologist, which is composed of various strata and zones.

Let us in brief outline consider a dune-formation. High winds blowing upon a sandy shore blow the sand inland, and it accumulates in the form of dunes or sand-hills. These dunes frequently shift unless they are covered with vegetation. A dune is to all intents and purposes a desert, but yet it can be colonized by xerophytes, which are adapted to life in physically dry conditions. A shifting dune may become "fixed" by the vegetation which occupies it. While the dune is yet liable to shifting under the influence of high winds, and its seaward side is bare, the landward slopes become occupied by various xerophytes, and the crest is tackled by the Sea-Maram Grass (*Psamma arenaria*), which has very long creeping rootstocks that penetrate deeply into the sand in search of moisture, and very materially assist in binding the sand and fixing it so that it is not so readily dispersed by wind. The Maram Grass is followed by other plants, all with long roots and devices which check transpiration. Among the plants that colonize the dune, particularly on its landward slopes, are the Sand Sedge (*Carex arenaria*), the Sea-Holly (*Eryngium maritimum*, Plate LXXII.), the Rest-Harrow (*Ononis arvensis*), the Sow-Thistle (*Sonchus oleraceus*), Sea-Buckthorn (*Hippophœ rhamnoides*), Henbane (*Hyoscyamus niger*, Plate XX.), and the Yellow-Horned Poppy (*Glaucium luteum*, Plate LXXIII.).

At a later stage the dune is more settled, but the Maram Grass remains dominant and other species already mentioned may persist. But in time many new plants gain foothold and become abundant. Among these are Wild Thyme (*Thymus Serpyllum*), Lady's Bedstraw (*Galium verum*), Stork's-Bill (*Erodium cicu-*

BOGBEAN or BUCKBEAN (*Menyanthes trifoliata*),
ORDER *GENTIANACEÆ*.

arium, Plate LXVII.), Bird's-Foot Trefoil (*Lotus corniculatus*) and Centaury (*Erythræa Centaurium*). Later still, the Maram Grass is ousted and the Sand Sedge and Sheep's Fescue Grass become dominant. Other plants take up stations, among them Stonecrops, Mouse-Ear Hawkweed (*Hieracium Pilosella*, Plate XXIX.), Whitlow Grass (*Draba verna*) and Sandwort (*Arenaria serpyllifolia*). The shifting dune is transformed by its plant-colonists into a fixed dune, and ultimately the formation is closed, becoming dominated by pasture grasses or transformed into a heath in which Ling (*Calluna vulgaris*, Plate LXIII.) is usually dominant.

From this outline it will be seen that the dune-formation is at first "open," and continues to be so for some time. It is occupied by a succession of associations until it becomes fixed and closed, the final and permanent association consisting of comparatively few species. It is apparent that there is a struggle for existence among associations as well as among individual species.

Mention of this succession of associations reminds the author of a pond that he has had under observation for many years. A dozen or so years ago this pond was fairly clear and deep and a haunt of Water-lilies, and other aquatics. The Marsh Horsetail (*Equisetum limosum*) appeared on its margins and increased with great rapidity; a mass of decaying leaves and other detritus became entangled with the Horsetail and the pond is gradually being silted up, the Horsetail extending all over the area of the water and assisting in the process. The pond is now little more than a marsh, and marsh plants have followed the Horsetail wherever

it has established conditions suited to their needs. The Bog Bean (*Menyanthes trifoliata*, Plate LXXIV.), Marsh Marigold (*Caltha palustris*, Plate VIII.), Marsh Cinquefoil (*Comarum palustre*), Bog Pimpernel (*Anagallis tenella*, Plate XXV.) and Marsh Violet (*Viola palustris*) have taken hold. The silting-up process still proceeds, and is preparing the way for Queen of the Meadow (*Spiræa ulmaria*, Plate LXVIII.) and other plants which are even now encroaching on the Marsh association. If the development is not arrested, the pond will entirely disappear, and its area be occupied by a Grassland association which will be invaded by Alders (*Alnus glutinosa*, Fig. 68) and Willows, which are already in close proximity.

We may speak of "fixed" formations, but the term is relative, not absolute. A formation will remain fixed so long as the ecological factors do not change; when the equilibrium of these factors is disturbed, a formation changes. Man in his determination to conquer Nature and cultivate her soil is a disturbing factor, and in a country like England, which has been under cultivation for many centuries, there are great areas in which ecological determinations are difficult to arrive at. Yet on British heaths, moors, and seashores, with their dunes and salt-marshes, we have excellent opportunities for ecological study.

In the hands of the zealous ecologist the science of botany has a great future. Already the study has given a considerable impetus to field work. It has "caught on" in America and on the Continent, and is developing satisfactorily in Britain. We look forward to the time when an ecological survey of the world's

vegetation will be undertaken, and in due course completed.

Professor Warming, who was the first to undertake a systematic study of plant-communities, is still living, and his work *The Ecology of Plants* is a classic among his followers. A. G. Tansley's *Types of British Vegetation* is an excellent guide to British workers. It contains contributions from various members of the Central Committee for the Study and Survey of British Vegetation.

Here we leave the subject. To have considered it in closer detail would have taken us beyond the limits of the present volume. Our treatment has been inadequate, but we trust we have indicated, in brief space, what plant-ecology is and how comprehensive is the scope of the " new field-botany."

GENERAL AND GLOSSARIAL INDEX

Pages on which terms are explained are indicated by figures in bold type.

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